DOCUMENT RESUME

ED 099 027 CE 001 073

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TITLE The Story of the Plastics Industry.
INSTITUTION Society of the Plastics Industry, Inc., New York, N.Y.
PUB DATE Oct 72
NOTE 44p.

EDRS PRICE MF-$0.75 HC-$1.85 PLUS POSTAGE
DESCRIPTORS Chemical Industry; *Development; *Industry; Manufacturing; *Merchandise Information; Organic Chemistry; *Plastics; Production Techniques
IDENTIFIERS *Plastics Industry

ABSTRACT

This is an illustrated informative booklet, designed to serve members of the Society of the Plastics Industry, Inc., and the plastics industry as a whole. It provides basic information about the industry's history and growth, plastics raw materials, typical uses of plastics, properties, and methods of processing and fabricating. (Author/DS)

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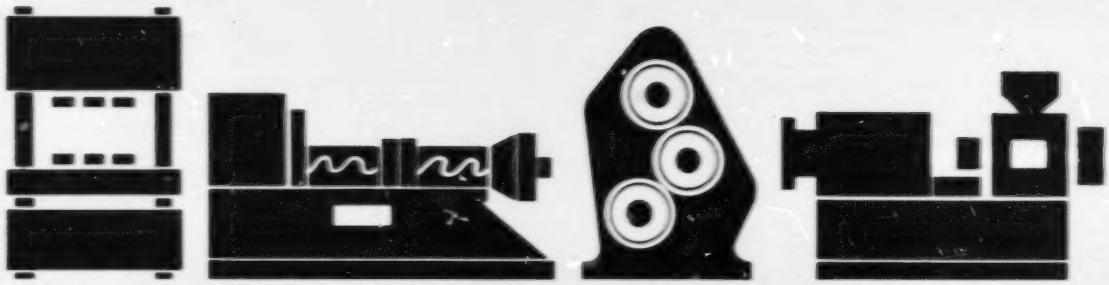

The story of the Plastics industry

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FOREWORD

This is an informative booklet, designed to serve members of The Society of the Plastics Industry, Inc., and the plastics industry as a whole. It provides basic information about the industry's history, growth, plastics raw materials – typical end uses with illustrations, properties, methods of processing and fabricating. It should not be considered as an encyclopedia or technical directory.

Additional copies of this booklet may be obtained at cost from the Public Relations Committee of SPI for distribution to employee groups, civic organizations and educational institutions.

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TWELFTH REVISED EDITION

Prepared under the direction of
The Public Relations Committee
THE SOCIETY OF THE
PLASTICS INDUSTRY, INC.
250 Park Avenue, New York, N. Y. 10017

Edited by Don Masson

Printed by The John B. Watkins Company

October, 1972

The story of the Plastics industry

In 1868, a young printer mixed pyroxylin, made from cotton and nitric acid, with solid camphor. John Wesley Hyatt came up with Celluloid, the first American plastic. Even more important, he started what is now one of the few billion dollar industries in the United States – the plastics industry.

Now in its greatest growth period, the U. S. plastics industry in 1969 produced over 16 billion pounds of resins. With a more than 200 per cent increase in production in the last ten years, the industry has grown both in volume and in variety of materials, each with special properties.

More and more businessmen have sought information on how plastics can improve their products, cut their costs, streamline their production. Students, technicians, workers have sought facts on employment opportunities, plastics courses offered by colleges and trade schools, and supplementary information sources.

The growth of the plastics industry has been so rapid, however, that public awareness of the sources of information on the major plastics, their characteristics and proper use has not kept abreast of the interest of either the businessman or the student.

This booklet is prepared by The Society of the Plastics Industry, Inc., representing 1,350 companies engaged in some phase of the plastics industry, to answer basic questions about the industry, its materials and production methods.

How the Industry Grew

A century ago there was no such thing as a commercial plastic in the United States. We had not learned that by combining such basic organic materials as oxygen, hydrogen, nitrogen, chlorine and sulfur, new man-made materials could be created – materials which, through variations in the amount and combination of basic organic and inorganic ingredients, could be made with almost any quality desired in an end product.

In creating the first commercial plastic in the United States in 1868, John Wesley Hyatt did so in response to a competition sponsored by a manufacturer of billiard balls. It came about when a shortage developed in ivory from which billiard balls were made. Hyatt, a determined full-time printer and part-time inventor, developed Celluloid. Concurrently, in England, development was in progress on the use of pyroxylin in lacquers and in other coating materials.

Celluloid, the first American plastic, was soon found to have many uses. Colored pink, it was quickly adopted by dentists as a replacement for hard rubber in denture plates. It will be remembered as the material from which wipe-clean collars, cuffs and shirt fronts were made, and as the window curtains on the early automobiles. The first photographic film used by Eastman was made of Celluloid in the '80's to produce the first motion picture film in 1882.

Forty-one years were to pass before the plastics industry took its second major step forward. In 1909, Dr. Leo Hendrik Baekeland introduced phenol-formaldehyde resins. While others in the field of chemistry had experimented with the combination of phenol and formaldehyde, Dr. Baekeland was the first to obtain a controllable reaction between the two. The first phenolic in this country was given the trademark, Bakelite, coined from his name.

Dr. Baekeland was also the first to develop techniques for converting this plastic to commercial use. His patents covered the production of a phenolic that could be cast (like marbleized clock bases), a compound that could be formed under heat and pressure (like an electric iron handle), and solutions that could be used in making laminates (like restaurant table tops).

From 1909 to 1926 two more plastic materials were developed – cold molded and casein. Then, the tempo of plastics development increased consistently as is evident in the accompanying list which gives the year each plastic was introduced and identifies it with a familiar product for each type of plastic.

Cellulose acetate was the next large-volume plastic to be developed commercially in this country. Launched in 1927, it was available only in sheets, rods and tubes until 1929 when it appeared as a molding material and became the first injection-molded plastic.

The first of the vinyl resins, polyvinyl chloride, came on the market in this country in 1927. The vinyls now constitute quite a family of resins, the most important of which – besides polyvinyl chloride – are polyvinyl acetate, polyvinyl chloride-acetate, polyvinyl acetal, polyvinylidene chloride.

While polystyrene became commercially available in this country in 1938, it is one of the oldest synthetic resins. It dates back to 1831 when it was first isolated. Today, polystyrene is one of the volume plastics, most familiar in toys and housewares.

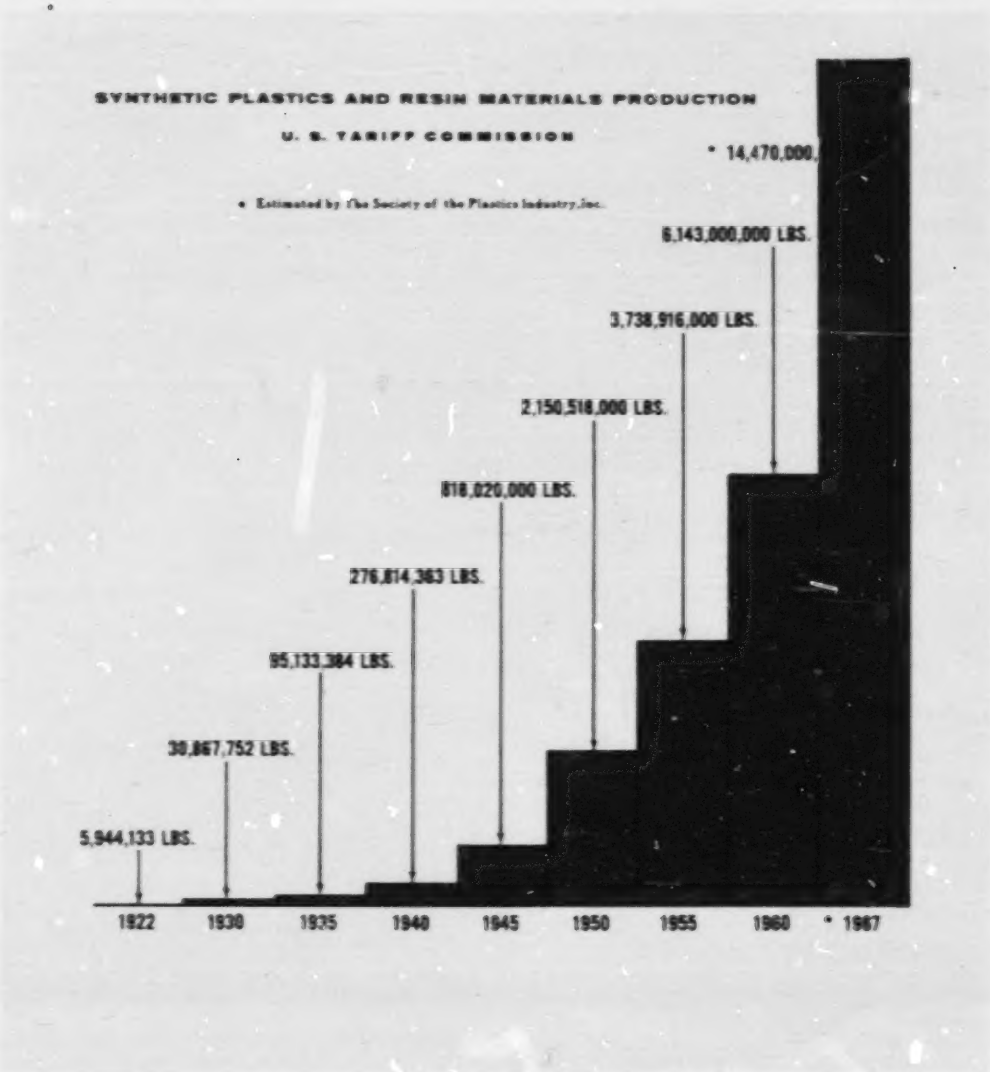
Polyethylene was introduced in 1942. It was originally produced in England and first made in the United States for the U. S. Navy as an important electrical insulation. Polyethylene became the first plastic to reach a billion pound annual production rate.

INTRODUCTION OF PLASTICS MATERIALS

DATE	MATERIAL	EXAMPLE
1868	CELLULOSE NITRATE	EYE GLASS FRAMES
1909	PHENOL-FORMALDEHYDE	TELEPHONE HANDSET
1909	COLD MOLDED	KNOBS AND HANDLES
1919	CASEIN	KNITTING NEEDLES
1926	ALKYD	ELECTRICAL BASES
1926	ANALINE-FORMALDEHYDE	TERMINAL BOARDS
1927	CELLULOSE ACETATE	TOOTH BRUSHES, PACKAGING
1927	POLYVINYL CHLORIDE	RAIN COATS
1929	UREA-FORMALDEHYDE	LIGHTING FIXTURES
1935	ETHYL CELLULOSE	FLASHLIGHT CASES
1936	ACRYLIC	BRUSH BACKS, DISPLAYS
1936	POLYVINYL ACETATE	FLASH BULB LINING
1938	CELLULOSE ACETATE BUTYRATE	IRRIGATION PIPE
1938	POLYSTYRENE OR STYRENE	KITCHEN HOUSEWARES
1938	NYLON (POLYAMIDE)	GEARS
1938	POLYVINYL ACETAL	SAFETY GLASS INTERLAYER
1939	POLYVINYLIDENE CHLORIDE	AUTO SEAT COVERS
1939	MELAMINE-FORMALDEHYDE	TABLEWARE
1942	POLYESTER	BOAT HULLS
1942	POLYETHYLENE	SQUEEZABLE BOTTLES
1943	FLUOROCARBON	INDUSTRIAL GASKETS
1943	SILICONE	MOTOR INSULATION
1945	CELLULOSE PROPIONATE	AUTOMATIC PENS AND PENCILS
1947	EPOXY	TOOLS AND JIGS
1948	ACRYLONITRILE-BUTADIENE-STYRENE	LUGGAGE
1949	ALLYLIC	ELECTRICAL CONNECTORS
1954	POLYURETHANE OR URETHANE	FOAM CUSHIONS
1956	ACETAL	AUTOMOTIVE PARTS
1957	POLYPROPYLENE	SAFETY HELMETS
1957	POLYCARBONATE	APPLIANCE PARTS
1959	CHLORINATED POLYETHER	VALVES AND FITTINGS
1962	PHENOXY	BOTTLES
1962	POLYALLOMER	TYPEWRITER CASES
1964	IONOMER	SKIN PACKAGES
1964	POLYPHENYLENE OXIDE	BATTERY CASES
1964	POLYIMIDE	BEARINGS
1964	ETHYLENE-VINYL ACETATE	HEAVY GAUGE FLEXIBLE SHEETING
1965	PARYLENE	INSULATING COATINGS
1965	POLYSULFONE	ELECTRICAL ELECTRONIC PARTS

The plastics industry runs into billions of both dollar volume of finished products and in the pounds of raw material produced. Three plastic materials have reached or exceed 2 billion pounds annual production: Polyethylene – 3.8 billion; Vinyl – 2.8 billion; and Styrene – 2.5 billion. The Society of the Plastics Industry, Inc., estimates that the production of all synthetic plastics and resin materials in 1967 was about 14.47 billion pounds. This fact, alone, is indicative of the importance of the plastics industry in our world today.

Plastics companies numbering over 5,700 are located throughout the United States. Approximately 50 per cent are in the East, 34 per cent in the Midwest, 13 per cent on the West Coast, and 3 per cent elsewhere.



Plastics – Partner of Today's Living

Plastics play a vital role in peace, defense, and in war. They were instrumental in the development of the automobile, airplane, missile and communications. They provided the material needed to develop the automobile ignition system. They made possible the pioneering flights of Alcock and Brown, Lindbergh, Byrd, Shepard, and Glenn. It is said that the Wright Brothers in the '80's used plastics – cellulose nitrate solutions on glider wings and on the wings of the plane in which they made their historic flight in 1903.

The lifelines of all communications – telephone, radio, television, radar, sonar, telestar – are based on plastics as insulation and other vital components. The comfort of our homes is increased in countless ways . . . through foamed cushions for furniture, easy-to-clean upholstery, protective coatings for the home and industrial equipment, soft illumination for translucent lighting, floor coverings that are resistant to spilled liquids and foods. All of these and many more can be attributed to resins and plastics. Without them we might soon be back in the "dark ages."

The continuing development of new plastic materials broadens the industry's field of applications. Even more, it is indicative of plastics' ability to produce equally good products at a lower cost, better products at the same cost, or products that could not be manufactured without them.

World War II gave great impetus to the industry. In meeting exacting defense service requirements, plastics demonstrated their versatility and wide range of important properties. They proved their high tensile and impact strength, lightness, resistance to corrosion, low moisture absorption, resistance to salt water and many chemicals, transparency, adaptability to varied climatic conditions, and flexibility even at low temperatures.

Designers, engineers, and architects constantly analyze material and performance requirements of varied products to determine the suitability of plastics for new end uses; and plastics materials are being formulated with scientific precision and skill to meet these new market applications.

The plastics industry is continuing to expand its facilities of research, development and production . . . to meet both civilian and defense requirements. The Society of the Plastics Industry, Inc., estimates that since 1946 the plastics industry has at least tripled its investments in raw materials plastics plants. Hundreds of millions of dollars are being spent in plastics research for the development of new resins and the improvement of existing plastics to meet the multifold requirements of modern industry.

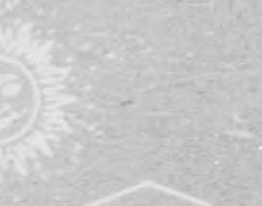
Today, plastics are accepted as basic materials used by designers and engineers. They take their place in industry along with metal, glass, wood and paper.

Plastics: What They Are

Plastics are man-made materials, in contrast to nature's materials like wood and metal. A generally accepted definition is: Any one of a large and varied group of materials consisting wholly or in part of combinations of carbon with oxygen, hydrogen, nitrogen and other organic and inorganic elements which, while solid in the finished state, at some stage in its manufacture is made liquid, and thus capable of being formed into various shapes, most usually through the application, either singly or together, of heat and pressure.

THERMOPLASTIC:

These plastics become soft when exposed to sufficient heat and harden when cooled, no matter how often the process is repeated. In this group fall ABS (acrylonitrile-butadiene-styrene), acetal, acrylic, the cellulosics, ethylene-vinyl acetate, fluorocarbon, ionomer, nylon, parylene, phenoxy, polyallomer, polycarbonate, polyethylene, polyphenyl oxide, polyimide, polypropylene, polystyrene, polysulfone, urethane, and vinyl.



THERMOSETTING:

The plastics materials belonging to this group are set into permanent shape when heat and pressure are applied to them during forming. Reheating will not soften these materials. Thermosetting plastics include: alkyd, amino (melamine and urea), casein, cold molded, epoxy, phenolic, polyester, and silicone.

Plastics are a family of materials – not a single material – each member of which has its special advantages.

Being man-made, plastics raw materials are capable of being variously combined to give most any property desired in an end product. But these are controlled variations unlike those of nature's products.

The widespread and growing use of plastics in almost every phase of modern living can be credited in large part to their unique combinations of advantages. These advantages are light weight, range of color, good physical properties, adaptability to mass-production methods and, often, lower cost. Some plastics can be sterilized.

Aside from the range of uses attributable to the special qualities of different plastics, these materials achieve still greater variety through the many forms in which they can be produced.

They may be made into definite shapes like dinnerware and electric switchboxes.

They may be made into flexible film and sheeting familiar as shower curtains and upholstery.

They may be made into sheets, rods and tubes that are later shaped or machined into internally-lighted signs, airplane blisters.

They may be made into filaments for use in household screening, industrial strainers and sieves.

They may be made into netting in a variety of patterns and sizes.

They may be used as a coating on textiles and paper.

They may be used to bind together such materials as fibers of glass and sheets of paper or wood to form boat hulls, airplane wing tips, table tops.

They may be used as adhesives, and in lacquers and paints – uses which are but mentioned in this booklet which deals specifically with solid forms of plastics.

Whatever their properties or form, plastics all fall into one of two groups – the *thermoplastic* or the *thermosetting*.

The Industry That Produces Plastics

Today, a minimum of 5,700 companies in the United States make plastics their business. They divide into three large categories which sometimes overlap – the plastics materials manufacturer who produces the basic plastic resin or compound, the processor who converts plastic into solid shape, the fabricator and finisher who further fashions and decorates the plastic.

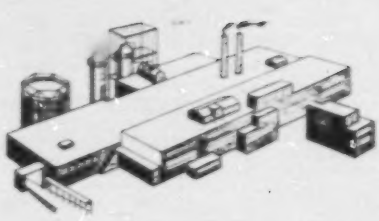
PLASTICS MATERIALS MANUFACTURERS

The primary function of the materials companies is the formulation of a plastic from basic chemicals. This plastic compound is sold in the form of granules, powder, pellets, flake, and liquid resins or solutions for processing into finished products. Some plastics materials companies may go a step further and form the resin into sheets, rods, tubes, film.

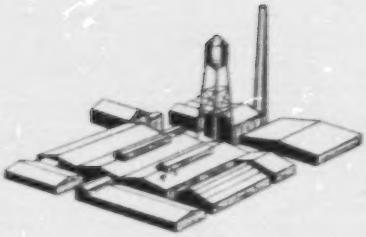
The membership of The Society of the Plastics Industry, Inc. lists 175 companies as manufacturers of plastics materials in the United States. A majority are chemical manufacturing companies. Some purchase chemicals from which they formulate the plastic resins and compounds. Some only make the compound, purchasing the resin.

THE PROCESSOR

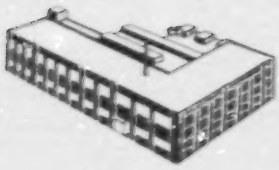
Plastics processors divide into several different classifications:



MATERIAL MANUFACTURERS



MOLDERS



FABRICATORS

MOLDERS – produce finished products by forming the plastic in a mold of the desired shape. They number about 1,700.

EXTRUDERS – divide into two groups. The first group turns out sheets, film, sheeting, rods, tubing, special shapes, pipe, wire covering. The second group includes producers of the thread-like plastic filaments which, when woven into cloth, find use as seat covers for autos, buses, trains and furniture, and as insect and industrial screening. Extruders number in all about 300.

FILM AND SHEETING PROCESSORS – make vinyl sheeting and film either by calendering, casting, or extruding. There are about 60 companies in the field.

HIGH-PRESSURE LAMINATORS – form sheets, rods and tubes from paper, cloth and wood impregnated with resin solutions. These companies are about 50.

REINFORCED PLASTICS MANUFACTURERS – Liquid resins–polyesters, epoxies, phenolics, and silicones – are combined with such reinforcements as glass fibers, asbestos, synthetic fibers and sisal to form strong, rigid structural plastics and plastic products by molding or forming. There are about 400 companies.

COATERS – make use of calendering, spread coating, preimpregnating, and dipping and vacuum deposition to coat fabric, metal and paper with plastics. They number over 70.

THE FABRICATOR AND FINISHER

Plastics sheets, rods, tubes and special shapes are the principal forms with which fabricators and finishers work. Using all types of machine tools, they complete the conversion of these plastics forms into such finished products as industrial parts, jewelry, signs

Vacuum forming is an important method of fabricating sheet materials. Working with rigid sheet material, fabricators also form such things as airplane canopies, television lenses.

One of the newest and largest branches of the plastics industry comprises companies that produce from plastic sheeting and film such articles as shower curtains, rainwear, inflatables, upholstery, luggage, closet accessories.

Between the producer of the film and sheeting and the fabricator of a finished product there may be a printer who prints a design on the material, and an embosser who forms a textured pattern on its surface.

Other finishers metal-plate rigid plastic parts or otherwise give them decorative or practical surface markings.

There are approximately 1500 fabricators working on rigid plastics and another 1500 engaged in making film and sheeting into finished products.

The Plastics Materials They Work With

ABS PLASTICS — ACRYLONITRILE-BUTADIENE-STYRENE

ABS plastics are thermoplastic materials developed in 1948. There is also a SAN (styrene-acrylonitrile) version of this family of plastics.

TYPICAL USES

Pipe, pipe fittings, wheels, football helmets, safety helmets, textile bobbins, TV antenna brackets, valve bodies, refrigerator parts, battery cases, automotive parts, cable floats, tote boxes, water pump impellers, terminal blocks, strike brackets, business machine trays, children's skates, utensil handles, tool handles, radio cases are typical products.

PROPERTIES

Strong and tough • ABS plastics possess outstanding impact strength in combination with high mechanical (tensile, flexural, etc.) strength. Some formulations offer excellent toughness down to −60°F.

Heat resistance • These compounds can be used at temperatures of 175°F. to 212°F. Newer formulations withstand temperatures greater than 212°F.

Chemical resistance • ABS plastics are resistant to acids, alkalis, salts and, in many cases, to aliphatic hydrocarbons.

Electrical qualities • ABS plastics have good overall electrical properties.

Dimensional stability • Parts are dimensionally stable under a wide variety of conditions.

FORMS AND METHODS OF FORMING

ABS plastics are available as powder or granules for injection molding, extrusion and calendering and as sheet for vacuum forming.

ACETAL RESIN

Acetal resin is a rigid thermoplastic developed in 1956.

TYPICAL USES

This resin was developed for use in fields once dominated by die-cast metals. Uses include automobile instrument clusters, carburetor parts, gears, bearings and bushings, door handles, plumbing fixtures, and moving parts in home appliances and business machines.

PROPERTIES

Rigidity • Acetal resin is extremely rigid without being brittle. It retains these properties under adverse conditions of temperature and humidity.

Chemical resistance • Resistant to most solvents.

Odorless, tasteless, non-toxic.

Strength • Extreme toughness, outstanding tensile strength, stiffness, and fatigue life.

FORMS AND METHODS OF FORMING

Acetal resin is produced in powder form for molding and extrusion.

ACRYLIC

Acrylic, or polymethylmethacrylate, plastic is a thermoplastic material, commercially introduced in the U.S.A. in 1936. A copolymer, methyl methacrylate-styrene is also available.

TYPICAL USES

Airplane canopies and windows, camera lenses, facing panels, dome structure enclosure glazing in building construction, outdoor signs, lighting diffusers, automobile tail lights, nameplates for home appliances, TV shields, and skylights.

PROPERTIES

Optical clarity • Acrylics offer exceptional clarity and good light transmission. In crystal-clear form, acrylic can pipe light – pick it up at one edge and transmit it unseen, even around curves.

Strength • Acrylics are strong, rigid and resistant to sharp blows. Contact with cleaning cloths containing grit, kitchen scouring powders and such abrading materials as steel wool should be avoided.

Weather and temperature resistance • Weathering does not affect the transparency, physical stability and electrical properties of acrylic. Long outdoor exposure of colorless acrylic has no significant effect on its use as a transparent material. Acrylic does not become brittle at low temperatures. Some cast acrylic compositions withstand boiling water, and heat-resistant molding compositions are undistorted up to 200°F. Acrylics will not withstand steam sterilizing and, if subjected to boiling water, will start to lose shape. This acrylic plastic material has a slow burning rate and does not flash ignite.

Electrical properties • Acrylic is an excellent insulator.

Color and texture • Acrylics are inherently colorless but are also produced in a full range of transparent, translucent and opaque colors. They are also made with corrugated and patterned surfaces. This plastic is warm and pleasant to the touch.

Odorless, tasteless, non-toxic.

Chemical resistance • Acrylics are unaffected by most household chemicals such as weak and strong alkalis, bleaching compounds and window cleaning solutions, by salt, vinegar, animal and mineral oils, waxes, and foods commonly encountered in the home. This plastic is attacked by perfume, gasoline, cleaning fluids, acetone, chloroform, and strong solutions of oxidizing acids.

FORMS AND METHODS OF FORMING

Acrylics are available as rigid sheets, rods and tubes, and molding powders.

Plastic products can be produced by fabricating of sheets, rods and tubes, hot forming of sheets, injection and compression molding of powder, extrusion, casting.

ALKYD

Alkyd plastic is a thermosetting material, developed in 1926, which has its widest application in enamels, paints, lacquers and similar applications. It was introduced as a molding material in 1948. Production in 1967 is estimated at around 680,000,000 lbs.

TYPICAL USES

Representative applications of alkyd molding materials are parts of automobile starters, fuses, light switches, electric motor insulator and mounting cases, television tuning devices and tube supports. Enamels and lacquers for automobiles, refrigerators, stoves, farm machinery are typical uses for the liquid form of alkyd plastic.

PROPERTIES

Electrical properties • Alkyd molding materials have excellent dielectric strength and will resist more than 350 volts per mil. They have high resistance to electrical leakage. Molded alkyd materials also afford excellent arc resistance.

Weather and temperature resistance • Alkyd molding powders have excellent heat resistance and are dimensionally stable under high temperatures. They also have good resistance to moisture.

Chemical resistance • Molded alkyd is resistant to acids, ketones, esters, alcohol, chlorinated compounds, essential oils.

FORMS AND METHODS OF FORMING

Alkyds are available as molding powder and liquid resin.

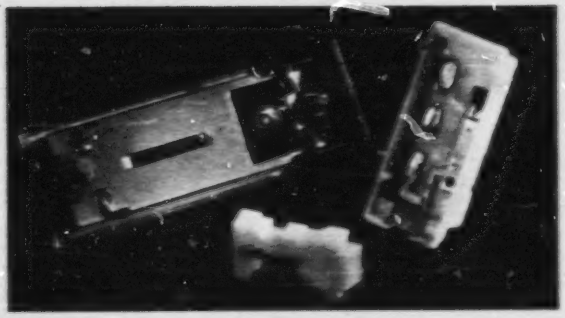
Finished molded products are produced by compression molding.

1

2

1. Automotive parts molded of acryionitrile - butadiene - styrene plastic. Metallized dash panels and instrument cluster take look of metal, but incorporate greater durability and impact resistance.

2. Colorful telephone desk sets are molded of ABS plastic which provides outstanding impact strength and is unaffected by perspiration.



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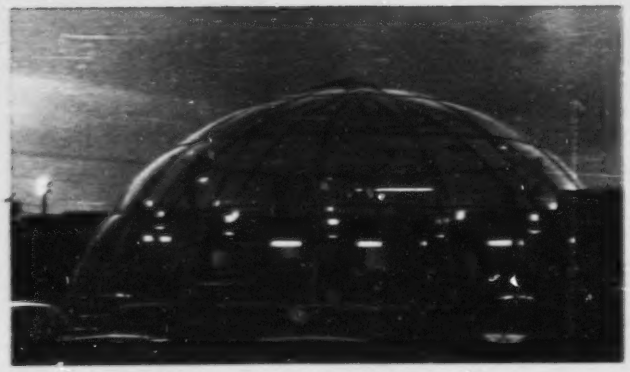
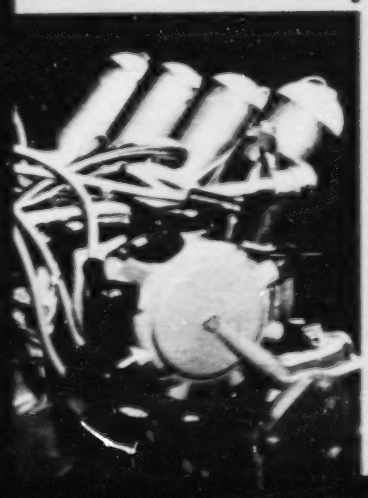
3. Acetal molded switch back (foreground) for electric windshield wiper control is fitted to metal housing above. The acetal molded slide (right) moves inside switch back and makes metal to metal contact with lugs to activate wipers and for speed control.



4

4. Weather and break resistance, light weight and clarity are reasons for using acrylic sheet for the dome enclosure.

5. Molded alkyd distributor cap used on racing car engine. Alkyd was used because of its high electrical surface resistivity and retention of superior electrical properties at under-the-hood racing temperature.



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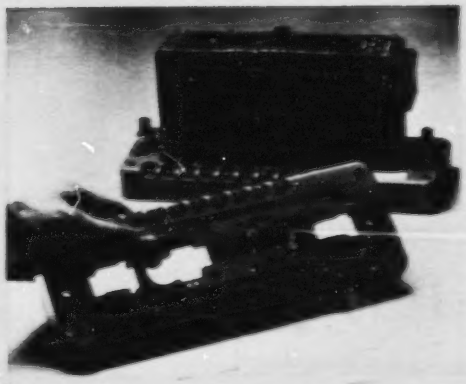

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6. Base of this circuit breaker, used in aircraft power generator systems, is molded of allylic. Use of glass-filled diallyl phthalate resin-base compound virtually eliminated rejects.

ALLYLIC

Allylics are thermosetting materials developed since World War II. The most widely used of its prepolymers, diallyl phthalate resin, was introduced commercially in 1949.

TYPICAL USES

Electronic parts, electrical connectors, bases, and housings, etc. Low and high pressure laminates, both reinforced plastics and decorative types.

PROPERTIES

Electrical • High dielectric strength, low electrical loss, low dielectric constant over a wide frequency range, excellent insulation resistance and arc resistance. Unmatched ability to retain its excellent electrical properties under conditions of high humidity with rapid and full recovery of properties on drying.

Heat, Moisture, Staining, Chemical, and Weather Resistance • Allylic plastics can be produced to withstand constant use at up to 350° F. and colored products have excellent color stability at high temperatures.

These plastics have practically no moisture absorption and are highly resistant to decomposition by practically all chemicals. Consequently, allylic plastics are highly stain resistant. Allylics have superior resistance to the adverse effects of weathering, and even thin overlays will greatly improve the weathering ability of other materials such as polyester glass fiber sheet.

Odorless, Tasteless, Insoluble.

Unusual Dimensional Stability During and After Molding.

Color • Allylic plastics can be produced in a full range of opaque and transparent colors which are stable under the most adverse conditions.

FORMS AND METHODS OF FORMING

Allylics are available in the form of monomers and prepolymers. Also available are ready-to-use molding powders with a variety of fillers or prepreg of coated glass fiber, other textiles, paper, etc.

Finished articles may be made by transfer, compression, injection or extrusion molding; lamination; coating, both powder and liquid; impregnation.

AMINO PLASTICS — MELAMINE AND UREA

Amino plastics are thermosetting materials. Melamine, developed in 1939, and urea, developed in 1929, together reached a production level in 1967 of approximately 740,000,000 lbs.

TYPICAL USES

Melamine • Familiar in colorful tableware, melamine also finds wide use in distributor heads, buttons and hearing aid cases. It is also used in laminate surfaces, like table tops, as a plywood adhesive, for baking enamel finishes, and as a textile and paper treatment.

Urea • Representative molded urea products are closures, scale housings, lamp reflectors, radio cabinets, electrical devices, buttons, appliance housings, stove knobs and handles. In resin form it is used as baking enamel coatings, plywood adhesives, and paper and textile treatment.

PROPERTIES

Colorful • Both melamine and urea offer a full range of translucent and opaque colors, colors which have the advantage of being lightfast. They give a glossy surface.

Strength • Both melamine and urea are very hard, scratch-resistant materials. They are strong but not unbreakable, and should be guarded against hard blows. There are special high shock-resistant and impact-resistant types.

Chemical resistance • Both melamine and urea are unaffected by detergents, cleaning fluids

(like carbon tetrachloride and gasoline), nail polish and remover, alcohol, oils, grease.

Heat and weather resistance • Melamine and urea perform satisfactorily over a wide temperature range from as low as −70°F. for both plastics to a continuous operating temperature of 170°F. for urea and 210°F. for melamine. They maintain their dimensions well and, for most indoor uses, may be considered completely permanent. Neither material should be used in an oven or over a flame, as discoloration or charring may occur. However, neither will burn or soften in contact with a flame.

Electrical characteristics • Both melamine and urea have good electrical qualities.

FORMS AND METHODS OF FORMING

The amino plastics (melamine and urea) are available as molding powders or granules, as a foamed material, in solution and as resins.

Finished products can be made by compression, transfer, plunger molding and laminating with wood, paper.

CASEIN

Casein, the product of the protein of skim milk reacted with formaldehyde, is a thermosetting material developed in 1919.

TYPICAL USES

Buttons and buckles, beads, game counters, knitting needles, adhesives, toys and novelty-counter items are all typical applications for casein plastic.

PROPERTIES

Color and appearance • Casein takes a brilliant surface polish and has a wide color range of near transparent and opaque colors. Many extremely interesting and unusual variegated patterned color effects can be achieved with this thermosetting material.

Strength • Casein is a strong, rigid plastic. It resists the effects of both blows and flexing.

Chemical resistance • Casein products withstand dry cleaning and are not adversely affected by contact with such liquids as gasoline, nail polish, organic solvents and chemicals.

Weathering and water resistance • Casein is adversely affected by humidity and temperature changes. Immersion in liquids for long periods at room temperature or short periods at boiling temperature will cause casein to absorb water, swell, soften and break easily. It becomes more brittle as the temperature drops below freezing, and withstands only moderately elevated temperatures without becoming pliable or discoloring. It is not recommended for continuous outdoor exposure.

FORMS AND METHODS OF FORMING

Casein is available in rigid sheets, rods and tubes, as a powder and liquid.

Finished products are made by machining of the sheets, rods and tubes.

CELLULOSICS

There are five types of cellulosics, all thermoplastic. Cellulose nitrate was developed in 1868, cellulose acetate in 1927, cellulose acetate butyrate in 1938, ethyl cellulose in 1935 and cellulose propionate in 1945. They reached a volume of approximately 195,000,000 lbs. in 1967.

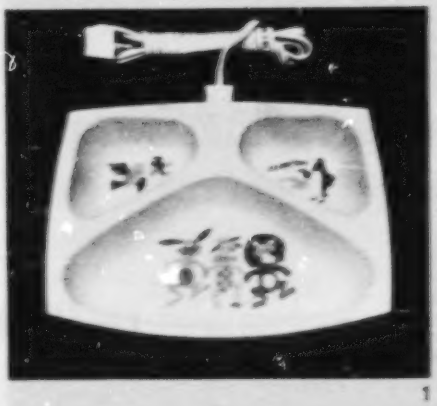
TYPICAL USES

Cellulose acetate is used for rigid packaging and is familiar as recording tape, photographic film, as a lamination for book covers, in spectacle frames, toys, lamp shades, vacuum cleaner parts, combs, shoe heels.

Cellulose acetate butyrate is used for packaging and in steering wheels, portable radio cases, pipe and tubing, tool handles.

Cellulose propionate is used in packaging, appliance housings, telephone hand sets, pens.

continued on page 15



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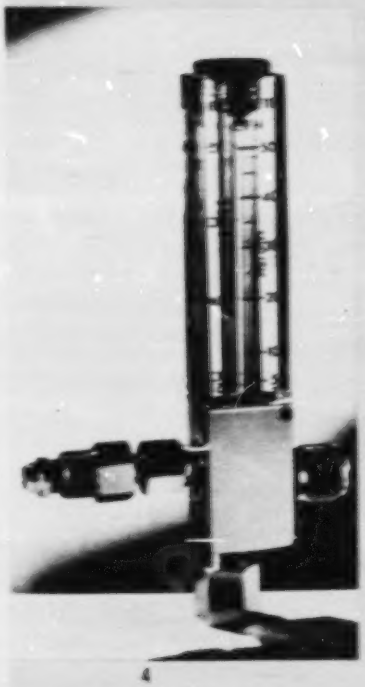
1. Electrically heated compartmented baby food dish is molded of melamine which resists attack from food, juices and detergents, and is break resistant.

2

2. Face-wide sun shade is made of colorfully printed cellulose acetate sheet. Shade is personal wind-and-sun shield that lets wearer look at world through new Op eyes. Flipped up, it becomes a bonnet; flipped down, a protective veil to cut glare and wind.

3. Transparent cellulose acetate butyrate pipe is used to blow cups several hundred feet from the manufacturing area to the packing and shipping department.



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4. Crystal-clear flowmeter column is made from extruded cellulose propionate plastic. Four-sided column on rotatable base permits direct and instant reading of flow rate for any of four inert industrial welding gases.

5

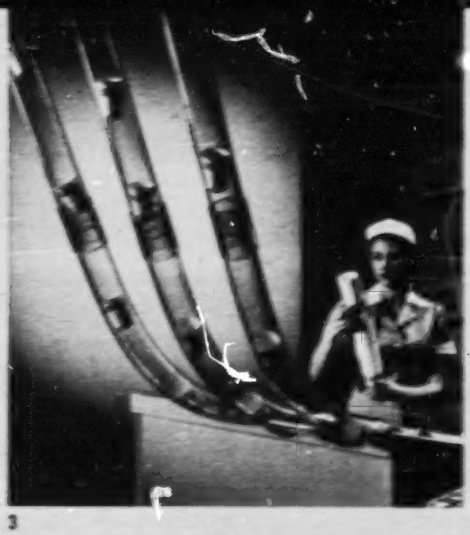
5. Cold molded plastics are used for electrical appliance connectors and plugs, wiring devices, heat resisting ferrules, adapters —where precision tolerances and heat resistance are prime factors.

6. Epoxy glass filament wound externally reinforced pressure vessel, showing the combination helical winding and circumferential winding to attain design requirements.

7

7. Epoxy-based surface coatings cure rapidly, withstand shock and exposure to chemicals, oil, grease and severe weathering.

8. One-use sanitary medical syringe eliminates costly sterilization. Syringe is blow-molded from ethylene-vinyl acetate, immediately packaged, and remains sterile and ready for use. Resin combines toughness, flexibility and clarity.



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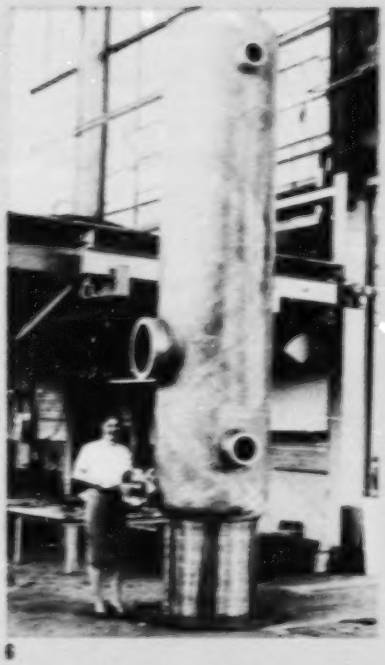

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8

Ethyl cellulose is favored for edge moldings on cabinets, electrical parts, flashlights.

Cellulose nitrate is familiar in shoe heel covers, and as a fabric coating.

PROPERTIES

Strong and durable • Cellulosics are among the toughest of plastics. Normal rough usage will not break cellulose parts. They retain a lustrous finish under normal conditions though abrasives will scar their surface.

Colorful • The cellulosics may be transparent, translucent or opaque in a wide variety of colors and in clear transparent.

Temperature and weather resistance • All the cellulosics will withstand moderate heat. Except for cellulose acetate butyrate and cellulose propionate which are suitable for outdoor use, cellulosics should not be exposed to continuous outdoor weathering.

Electrical characteristics • All the cellulosics have good electrical properties and are suitable insulators against usual domestic and industrial currents.

TYPES

Cellulose acetate (C/A) • This cellulosic is resistant to most household chemicals, oil, gasoline and cleaning fluids but should be kept away from alcohol, alkalies. This plastic is odorless, and tasteless. It is unaffected by normal moisture and moderate heat and will withstand normal usage at below freezing temperatures. Water resistance and dimensional stability are improved in high acetyl C/A.

Cellulose acetate butyrate (CAB) and Cellulose propionate (CP) • Special weather-resistant formulations of these cellulosics alone are suitable for outdoor use. Some types may be used in water approaching boiling, and all types can stand quite rough usage at sub-zero temperatures. Their moisture absorption rate is low. CAB and CP are resistant to most household chemicals, but are adversely affected by alcohol, alkalies, paint removers, acetone.

Ethyl cellulose (E/C) • Of the cellulosics, E/C best maintains its toughness and resiliency

continued on page 16

at sub-zero temperatures. It also offers good dimensional stability over a wide range of temperatures and humidity conditions. It is unaffected by alkalies, weak acids, but should be kept away from cleaning fluids, oils, solvents.

Cellulose nitrate (C/N) • This is made only as sheet, film, rod and tube and in solution for coating because it is flammable and cannot be subjected to molding. C/N offers a wide range of colors and variegated color effects. It is resistant to most acids and alkalies.

FORMS AND METHODS OF FORMING

Cellulose acetate is available as pellets, sheets, film, rods, tubes, strips, coated cord. It can be made into finished products by injection, compression molding; extrusion; blow-molding and vacuum forming of sheets; laminating; machining; coating.

Cellulose acetate butyrate is available in pellets, sheets, rods, tubes, strips, and as a coating. It can be made into finished products by injection, compression molding; extrusion; blowing and drawing of sheet; laminating; machining; coating.

Cellulose propionate is available in pellets for injection, extrusion, or compression molding.

Ethyl cellulose is available as granules, flake, sheet, rod, tube, film and foil. It can be made into finished products by injection, compression molding; extrusion; drawing; machining.

Cellulose nitrate is available as rods, tubes, film, sheets for machining and as a coating.

COLD MOLDED

Cold molded plastics are thermosetting materials developed in 1909. There are three types: bitumin, phenolic, and cement-asbestos.

TYPICAL USES

Cold molded plastics find use in switch bases and plugs, arc barriers and shoots, 3rd rail insulators, in small gears, handles and knobs, tiles, furnace covers, jigs and dies, in game markers and toy building blocks.

PROPERTIES

Cold molded plastics possess resistance to high heat, most alkalis and solvents, water and oils. They also exhibit good arc resistance.

FORMS AND METHODS OF FORMING

Cold molded plastic materials are available as compounds.

Finished articles are produced by molding using heavy pressure in a rapid cycle, and by subsequent curing.

The bitumin and phenolic types of cold molded materials are cured either in ovens or at room temperature.

The cement-asbestos type of cold molded material is first cured in the presence of moisture and it is then baked.

EPOXY

Epoxy resins are thermosetting and were first manufactured in the United States about 1947. Production totalled approximately 145,000,000 lbs. in 1967.

TYPICAL USES

Protective coatings for appliances, plant structure and equipment, automobiles, pipe, cans and drums, gymnasium floors and other hard-to-protect surfaces.

They firmly bond metals, ceramics, glass, plastics, hard rubber and are used in combination with glass fibers to manufacture reinforced plastics products. Other products are: Printed circuits, laminated tools and jigs, ducts and liquid storage tanks. Epoxies are employed most commonly in casting, potting, laminating, coating and adhesive-bonding applications.

PROPERTIES

Electrical qualities • Epoxies have good electrical properties.

Water and weather resistance • Epoxy base adhesives, due to their resistance to various chemi-

cals and weathering, may be used where corrosion resistant joints are required.

Chemical resistance • Epoxies are resistant to many chemicals. They have found widespread use for surface coating due to their excellent adhesion, durability and chemical resistance.

Strength • Epoxies have good flexibility.

FORMS AND METHODS OF FORMING

Epoxies are available as molding compounds, resins, foamed blocks, liquid solutions, adhesives, coatings, sealants.

ETHYLENE-VINYL ACETATE

Ethylene-vinyl acetate (EVA) copolymers are flexible thermoplastic resins. Moldable grades were developed in 1964.

TYPICAL USES

Present and potential uses for these new rubber-like plastics cover a variety of products, such as molded mechanical goods – milk dispenser tubing, syringe bulbs, hospital sheeting and similar hospital and pharmaceutical items. Others include shower curtains, greenhouse covers, disposable gloves, inflatable toys, and pool liners. Some grades meet Food and Drug Administration requirements for food packaging.

PROPERTIES

Flexibility • Flexible without plasticizer over a wide range of low and medium temperatures, including better low temperature flexibility when compared to vinyls.

Impact strength • High, even at extremely low temperatures.

Resilience • Excellent "snap-back."

Flex life • High resistance to flex cracking or environmental stress cracking.

FORMS AND METHODS OF FORMING

EVA molding compounds are formed by injection molding, extrusion and blow molding.

FLUOROCARBONS

Fluorocarbons are thermoplastic materials introduced in 1943. They include tetrafluoroethylene (TFE), chlorotrifluoroethylene (CTFE), vinylidene fluoride (PVF_2), and fluorinated ethylene-polypropylene (FEP).

TYPICAL USES

Fluorocarbon resins are used in industrial applications such as: gaskets and packings, seals, piston rings, and sealants (i.e. thread sealant tape), linings for vessels, valves, pumps, pipe and fittings, hose, etc., bearing pads, slip joints, pipe slides, expansion plates, anti-stick surfaces (in form of films, sheeting and coatings), electrical wire insulation and components; and other miscellaneous items (i.e. bellows, filters, pipe, tubing, and laboratory ware). They are used in consumer and household applications as coatings for frying pans, cooking utensils, rolling pins.

PROPERTIES

Chemical resistance • Fluorocarbon resins have unmatched chemical resistance to most industrial chemicals and solvents.

Thermal stability • Fluorocarbon resins retain useful properties from cryogenic to elevated temperatures, exceeding the temperature range of all other plastics.

Low coefficient of friction and anti-stick properties • Fluorocarbon resins have one of the lowest coefficients of friction known for solids and exhibit unmatched anti-stick characteristics.

FORMS AND METHODS OF FABRICATION

Fluorocarbon resins are applied as powders, granules or dispersions. They can be molded, extruded, hot or cold formed, machined, and are also applied as coatings.

1. Miniature, subminiature and microminiature terminals, molded and fabricated from fluorocarbons, are used for components for circuitry in TV, UHF microwave computers and other critical electronic circuits.

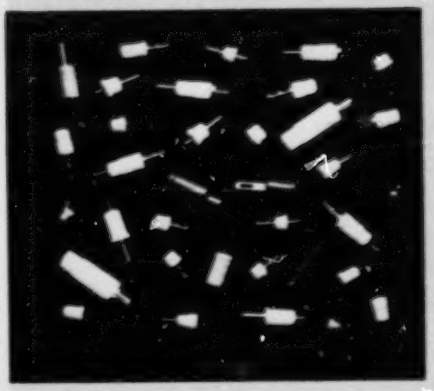
2. Plastic sheet compression-molded from ionomer resin has high transparency and flexibility. Quarter-inch sheet is easily flexed by girl, indicating use as face protection for industrial safety equipment.

3. Ionomer can be tailored for skin packaging of hardware items and other consumer products.

4. Auxiliary gasoline fuel tank for utility automobile is molded of nylon. Irregular in shape and made without seams or joints, the nylon tank is designed to fit into compact space below driver's seat. Using nylon, engineers were able to design tank to meet unusual space requirements.

5. Woven fabric of nylon monofilament is used for handbags and shoes in matching colors. Nylon fabric resists attack and staining by oil, grease and common chemicals.

6. Parylene-coated lithium-metal granules at left do not react with water on which they float. Unprotected granules at right react instantly and violently.



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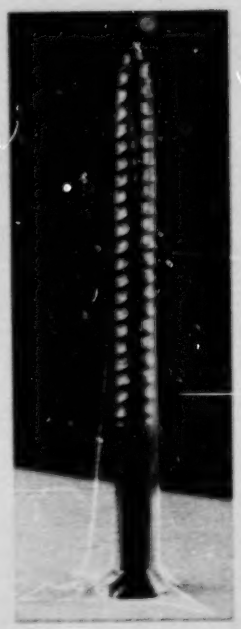

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IONOMER

The ionomers are a new family of thermoplastic resins developed in 1964. The term ionomer was coined to indicate that the polymer contains inorganic as well as organic materials linked by both covalent and ionic bonds.

TYPICAL USES

Ionomers can be tailored for a very wide variety of end uses; skin packaging applications, extrusion coatings and laminations for food packaging, molded items for housewares, toys, tool handles, bottles, closures and vials, wire and cable insulation, extruded shapes, tubing and sheeting. Flat sheeting can be thermoformed into covers, trays and irregular shapes.

PROPERTIES

Transparent and tough • Ionomers combine transparency with toughness, especially at low temperatures and are more resilient than polyethylene.

Chemical resistance • Ionomers are virtually unaffected by oils and greases. They are resistant to bases, dilute acids, hydrocarbons, ketones, alcohols and esters. Resistance to liquid absorption is high by comparison with many plastic materials of comparable transparency. Certain grades of ionomers are recommended for food packaging; meeting the requirements of food additives regulations.

Exceptional corona resistance in electrical insulation.

Tasteless, odorless.

Color • In the natural state it is crystal clear. This new resin can be readily colored with complete uniformity and has a high capacity level for fillers while retaining serviceable properties.

Adhesion • Ionomers can be heat sealed and can provide adhesion from a molten state to substrates, including metals.

FORMS AND METHODS OF FORMING

This plastic is injection molded, blow molded, extruded as shapes, film, substrate coatings and wire insulation, and thermoformed.

NYLON (POLYAMIDE)

Nylon, the generic name for a family of polyamide resins with related but not identical chemical compositions, is a thermoplastic material developed in 1938.

TYPICAL USES

Nylon is a familiar material for tumblers, slide fasteners, faucet washers, gears. As a filament it is used as brush bristles, fishing lines.

PROPERTIES

Resistant to extremes of temperature • Nylon can be safely boiled and steam sterilized. Also, freezing temperatures do not adversely affect it. However, nylon is not recommended for continuous outdoor exposure. It is self-extinguishing.

Strong and long wearing • Nylon is tough, having high tensile, impact and flexural strength. In part, its resistance to hard blows is due to its resiliency, allowing it to give a little when hit. Though the hard, glossy surface of nylon is very resistant to abrasion, scouring powders and steel wool should not be used in cleaning.

Chemical resistance • Nylon is unaffected by all common work-a-day chemicals, greases and solvents except mineral acids. It is fairly easily stained by coffee, tea and colored foods.

Electrical characteristics • Very good.

Color • Nylon varies from transparent to opaque depending on the thinness of the article. It comes in a range of soft colors.

FORMS AND METHODS OF FORMING

Nylon is available as a molding powder and as sheets, rods, tubes and filaments.

Finished products can be made by injection, compression, molding, blow molding, and extrusion.

PARYLENE

Parylene is a family of thermoplastic materials introduced in 1965.

TYPICAL USES

Sophisticated applications include: insulating and protective coatings for paper, fabric, ceramics, metals, and electronic parts such as photo cells, micro-circuits, memory units, and capacitors; encapsulation of reactive materials; and ultra-thin pellicles.

PROPERTIES

High-temperature resistance • Parylenes have high melting points (500°F.-750°F.) Thermal endurance in air is moderate, but for short term (1000 hr.) use, temperatures of about 200°F. to 240°F. are practical. For long term (10 yr.), data indicates that temperatures in the range of 140°F to 175°F. are optimum.

Cryogenic • Steel panels coated with parylene and chilled in liquid nitrogen to −320°F. withstand impacts of more than 100 in.-lb. in a modified falling ball impact test.

Dimensional stability • Parylene shows outstanding dimensional stability with respect to changes in relative humidity.

Chemical resistance • Parylenes resist attack and are insoluble in all organic solvents up to 300°F. They are unaffected by stress-cracking agents and are also resistant to permeation by all solvents with the exception of aromatic hydrocarbons. Gas and moisture vapor barrier properties are excellent.

Electrical • Dielectric properties of parylenes are extremely good. Near absolute zero, one type of parylene provides the best electrical insulation of any known plastic.

FORMS AND METHODS OF FABRICATION

Parylene can be deposited as a uniform, continuous, adherent film or formed on a surface treated with a release agent and then stripped free. Any material that can withstand relatively high vacuum can be coated.

PHENOLIC

Thermosetting phenolics were developed in 1909. Production was approximately 1.1 billion lbs. in 1967.

TYPICAL USES

Automobile distributor heads and insulation, telephone handsets, radio and television cabinets, electrical insulation, washing machine agitators, appliance parts, molded drawers, tube bases, bonds for abrasives, brake linings, protective coatings, juke box housing parts, novelties, jewelry, pulleys, handles, dials, knobs, laminated wood frame members.

PROPERTIES

Strong and hard • Phenolics are hard, rigid, strong. The average phenolic will withstand knocks, such as are common with camera housings. Special impact-resistant molding phenolics can be employed where use is even more rigorous. Their smooth, lustrous surface will give excellent service under severe conditions.

Heat and cold resistant • Phenolics have good heat resistance up to 300°F. and some above. Mineral and glass reinforced phenolics will perform up to 400°F. continuously. Moreover, they are poor conductors of heat, being cool to the touch when used as handles for cooking utensils. They do not support combustion or undergo change from freezing temperatures.

Electrical characteristics • Phenolics are excellent insulators. Special low-loss electrical insulating materials are available.

Chemical and water resistance • Water, alcohol, oils, greases and mild acids and common solvents do not adversely affect phenolic parts. Where extreme chemical resistance is required a special chemical resistant type is available. Phenolics, as a whole, do not absorb water and retain their luster, strength and rigidity.

Color • As molding materials they are opaque and are produced in black, brown, mottled walnut and dark colors. They tend to yellow upon exposure to light. Colorability distinguishes cast from molded phenolic. Cast phenolics are

produced in transparent, translucent and opaque colors, and in variegated effects.

TYPES

Phenol-formaldehyde • Molding materials are considered the "work horses" of the plastics industry. They are combined with various fillers – woodflour, chopped fabric, paper pulp, asbestos, mica – depending upon the ultimate use for which they are intended. These plastics are also produced as bonding resins, resins for protective coatings, adhesives. Finished products are made by compression, transfer, plunger molding; casting; laminating; coatings.

Cast phenolic • These are resins cast to form and are usually machined into finished products. They are strong, rigid and dimensionally stable, heat resistant, hard to scratch, water and chemical resistant. They are produced in a wide range of colors and variegated patterns, like onyx and marble. They are produced as sheets, rods, tubes and in special forms.

Phenol-furfural • This type has most of the properties of phenol-formaldehyde resins and plastics. It offers high strength, durability, dimensional stability and good electrical characteristics. Dark in color. Molding advantage is extended flow at low temperatures, fast cure at high temperatures. It is available as molding compounds, liquid resins, varnishes and cements. Phenol-furfurals are made into finished products by compression, transfer and injection molding; low-pressure molding; coatings; impregnating; laminates.

Resorcinol • This type is used primarily as room-setting adhesives in laminated gear blanks and laminated wood frame members. Outdoor exposure is good. Low temperature curing is an advantage in the lamination of heavy structures with thick sections. Resorcinols come as solids and liquids and are made into products by laminating; impregnating; coating; foaming.

FORMS AND METHODS OF FORMING

Phenolics are available as a molding compound to which different fillers may be added; as preforms, boards and blanks; for impregnants, bonding agents, coatings, foams. Finished products are made by: injection, compression, transfer, plunger molding; casting; laminating.

PHENOXY

Phenoxies are thermoplastic materials introduced in 1962.

TYPICAL USES

End uses for phenoxy compounds include clear blow-molded bottles, cosmetic, drug and food containers and other packaging applications; molded electronic parts for computers, electrical appliance housings; sporting goods and battery cases; extruded pipe; and in adhesives and coatings.

PROPERTIES

Optical • Crystal-clear, water-white phenoxy resins can be colored with dyes or pigments through the full range from delicate transparent tints to opaque colors.

Mechanical • Phenoxy exhibits an excellent balance of high rigidity, strength, hardness, and toughness, and is a practical engineering material. Parts can be economically and rapidly produced to meet tight tolerances and to hold their shape and size.

Thermal • Phenoxy retains its high tensile strength and rigidity right up to its heat distortion point. Fabricated parts can be used in load bearing applications at temperatures as high as 160° F. to 170° F.

Barrier • The permeability of phenoxy, particularly to oxygen, is the lowest of any melt-processable polymer. Oxygen permeability is 1/20 that of high density polyethylene.

Chemical • Phenoxy is resistant to attack by acids and alkalies, but swells and ultimately dissolves in solvents. It is also resistant to hydrocarbons, and most household cleaning compounds.

FORMS AND METHODS OF FORMING

Phenoxy pellets may be blow-molded, injection molded or extruded with ease. Finished parts are readily joined by conventional methods. Phenoxy is also supplied as resins for adhesives and as resins or in solution form for surface coatings.

POLYALLOMER

Polyallomers are a class of crystalline polyolefin polymers prepared from at least two monomers by copolymerization. The resulting polymer chains comprise polymerized segments of each of the monomers used.

Thermoplastic, propylene-ethylene polyallomer was developed and introduced in the United States in 1962.

TYPICAL USES

Automobile windlace and cowl panels, pipe fittings, self-hinged cases and containers, notebook binders, closures, toys, shoe lasts, film and sheet for packaging and vacuum forming.

PROPERTIES

Propylene-ethylene polyallomer combines many of the best characteristics of crystalline polypropylene and linear polyethylene.

Compared with general-purpose polypropylene, it offers lower brittleness temperature, higher impact strength, less notch sensitivity, and greater melt strength.

It offers better color, lower susceptability to blushing, and better moldability than impact-grade polypropylene. It also possesses superior resistance to fatigue from flexing . . . the "built-in" hinge property.

Compared with linear polyethylene, it offers superior processability, a higher softening point, greater dimensional stability and surface hardness, lower and more uniform shrinkages, and lower mold density. It possesses the outstanding dielectric properties common to the polyolefin plastics.

FORMS AND METHODS OF FORMING

Propylene-ethylene polyallomer can be processed by injection molding and extrusion on conventional thermoplastic equipment. Sheet made of polyallomer is generally superior to sheet made of other polyolefins for vacuum forming.

POLYCARBONATE

Polycarbonates are thermoplastics developed commercially in 1957.

TYPICAL USES

Polycarbonates are used to provide frameless design, where a combination of structural rigidity and outer housing are necessary in one part; and double insulation where a secondary outer housing is necessary to protect the operator when using an electrically operated device.

Air conditioner housings; handles of electric tools: power drills, saws, routers, impact wrenches, hedge clippers; home appliances: electric can openers and shavers; street light globes; lighting diffusion panels; lamp coatings; sunglass lenses and frames; telephone finger wheels; fishing reels; covers for baby food warmers and baby bottles; glazing; coffee pots; electrical connectors; blood oxygenators; rocket launcher handles; water pump impellers; electric knife handles.

PROPERTIES

Mechanical • Exceptionally high impact strength; heat resistance, rigidity, dimensional stability. Parts made from polycarbonate resin can take hammer blows without shattering and can withstand small caliber bullet force without being pierced or shattered. Polycarbonates can also be reinforced with glass fibers for even greater dimensional stability and rigidity.

Heat resistance • Polycarbonates maintain their stability at operating temperatures up to 240°F. Self extinguishing.

Electrical • Good.

Chemical resistance • Resistant to oil. Stain resistant. Non-corrosive.

Color • Transparent. Good colorability and gloss.

FORMS AND METHODS OF FABRICATION

Polycarbonate resin is primarily a molding material. It may also take the form of film, extrusions, coatings, fibers or elastomers.

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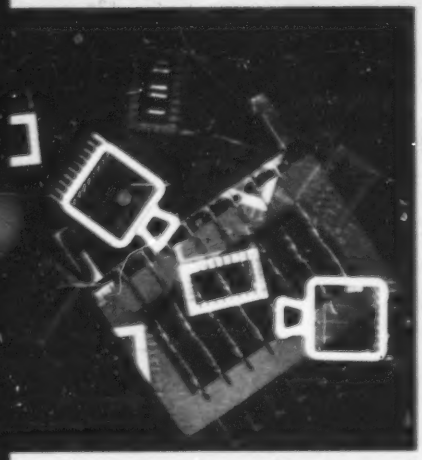

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1. A heavy metal frame for thi Braille typewriter has been re placed with a one-piece, mult part frame molded of hig strength phenolic. Frame i molded to tolerances as accu rate as .003 to permit carriag and other moving parts to func tion with fingertip ease.

2. Durable carrying case o polyallomer provides portabilit for industrial gas mask. Ligh weight 2 lb. case is molded i one piece and includes back front, hinges, handles and sna clasps. Case is strong enough t hold man's weight, resilien enough to resist impact an cracking. Integral hinges hav been tested 12 million time without cracking.

3. Low shrinkage and dimen sional stability give phenoxy th edge in molding the precisio frames necessary in these elec tronic sub-assemblies, known a diode sticks.

4. Visor of polycarbonate pro vides excellent optical prope ties and high strength protectio for astronaut during walk i space. Polycarbonate plastic wa strongest transparent materia tested.

5. Polyester reinforced fibe glass canoe is of sandwich con struction with high strength an low weight. A layer of poly urethane foam gives 150 poun flotation in excess of hull weigh

POLYESTER

Polyesters are thermosetting materials. Developed in 1942, they reached a production level of about 495,000,000 lbs. in 1967.

TYPICAL USES

Polyester resins are used to impregnate cloth or mats of glass fibers, paper, synthetic fibers, cotton and other fibers in the making of reinforced plastics for use in boats, automobile bodies, pipe, luggage, aircraft components, interior partitions and skylights or translucent roofs for buildings, scuff plates, film developing trays. They are used in cast form for jewels and lenses, and are combined with acrylics to produce pearlescent buttons that resist heat.

PROPERTIES

Adaptability to large parts • Products up to 500 sq. ft. in area are practicable because they can be formed under low or no pressure and at low or room temperatures.

Strength • These plastics are strong and tough. The strength, rigidity or flexibility of laminates and moldings may be varied through the selection of the reinforcing material. Polyesters have a superior surface hardness.

Chemical and water resistant • Polyesters are highly resistant to most solvents, acids, bases and salts. They also offer a low water absorption rate and good weathering qualities.

Electrical properties • These plastics have high dielectric qualities.

Colorability • These plastics can be made in a range of bright and pastel colors.

FORMS AND METHODS OF FORMING

Polyesters are produced as liquids, dry powders, premix molding compounds, and as cast sheets, rods and tubes. A special fire-retardant grade is available. Premix compounds are made from these basic resins to produce compression and transfer molded parts for automobiles, household utensils, electrical appliances, fixtures and tools.

They are formed by reinforcing, molding, casting, impregnating, premixing.

POLYETHYLENE

Polyethylene is a thermoplastic material. Developed in 1942, this plastic reached a production level of about 3.8 billion lbs. in 1967.

TYPICAL USES

Polyethylene is familiar as the material for flexible ice cube trays, tumblers, dishes, carboys and rigid and squeezable bottles, pipe and tubing, bags for candy and food products, rain capes, meteorological balloons, dry cleaners' bags for clothing, artificial flowers, greenhouses, silo covers, insulation, freezer bags, toys, moisture barriers under concrete and in walls, and coated paper for freezer wrap. Many of these products can be made with low, medium, or high density polyethylene, depending on the flexibility or rigidity required.

Some formulations are specifically approved by U. S. Food and Drug Administration regulations. Semi-conductive and vulcanizable polyethylene has recently been developed for outer jacketing on communications and power cables. Copolymers such as ethylene-vinyl acetate and ethylene acrylate are also available.

PROPERTIES

Strong and flexible • Depending on density, polyethylene is flexible or rigid. Either form is very resistant to breakage. Its surface is hard enough to withstand normal use but abrasive cleaners should be avoided.

Heat and cold resistant • This plastic can withstand temperatures down to −100°F. without becoming stiff and brittle. Also, some formulations may be subjected to boiling water and sterilization. It should not be used over an open flame or in a hot oven.

Electrical characteristics • Polyethylene offers excellent insulating properties.

Odorless, tasteless.

Resistant to water and weathering • Polyethylene is moistureproof, but allows passage of oxygen. Recommended for some outdoor applications.

Chemical resistant • This plastic is highly resistant to chemicals and is unaffected by food acids, household solvents and by short contact with cleaning fluids.

Color and appearance • This wax-like plastic is available as a clear transparent, translucent or opaque material. Made in a range of colors.

FORMS AND METHODS OF FORMING

Polyethylene is available in pellet form, powder, sheet, film, filament, rod, tube and foamed.

It may be made into finished articles by injection, compression, blow molding; extrusion, calendering, coating, casting, vacuum forming.

POLYIMIDE

Polyimides, a new class of non-melting plastics, were announced in 1962. They share the linear structure of the thermoplastics, yet, like thermosetting plastics, they have no measurable melting point.

TYPICAL USES

Polyimides are used in a wide range of applications in extreme environments at both high and low temperatures. Examples are aerospace parts, valve seats, bearings, seals and retainer rings. Industrial applications include compressor vanes, piston rings, bearing separators, connector inserts, and relay actuators. A polyimide film is produced for cable wrap, motor slot liners, formed coil wrap, flexible circuits, tapes, hose and tubing. A polyimide enamel is produced for wire insulation, and polyimide laminates and adhesives are also available.

PROPERTIES

Heat resistance • Excellent. Polyimides retain a significant portion of their room temperature mechanical properties up to at least 750°F. and can be used continuously in air at 500°F. without any loss of properties.

Electrical • Very good.

Wear resistance • Excellent frictional characteristics and very good wear resistance.

Other properties • Polyimides possess excellent bearing qualities, resist radiation, exhibit low out-gassing in high vacuum, and maintain their excellent properties at cryogenic temperatures.

FORMS AND METHODS OF FABRICATION

Polyimides are supplied in the form of finished precision parts, as wire enamel, laminates, adhesives, film, and as the resin bond in diamond abrasive products. Because polyimides do not melt, fabricated parts are made by machining, punching or by direct forming techniques.

POLYPHENYLENE OXIDE

Polyphenylene oxide resins are thermoplastics developed in 1964.

TYPICAL USES

Polyphenylene oxides have a wide range of applications as electrical insulating parts – battery cases, coil forms, computer modules – sterilizable medical and surgical instruments, household appliances exposed to hot water and plumbing equipment, including valves, pumps and plumber's brass goods.

PROPERTIES

Color • Presently opaque, beige.

Impact strength • Excellent.

Tensile strength • Polyphenylene oxide maintains a high level of strength and rigidity over a broad temperature range.

Dimensional stability • Parts molded of polyphenylene oxide withstand large loads for long periods of time without significant change in dimension. Parts possess high modulus and low creep.

Thermal • Polyphenylene oxide has a wide temperature range, a brittle point of approximately −275°F. and a heat distortion point of 375°F. at 264 psi.

Electrical • Polyphenylene oxide has excellent

continued on page 27

1. Blow-molded polyethylene bottles for industrial, automotive and chemical specialties are colorful, easy to handle, chemically resistant and often serve as self-dispensers.

2. High voltage submarine cable is protected with extruded polyethylene insulation, which ensures high dielectric strength, low dielectric loss, and excellent stability of electrical and physical properties when in contact with sea water.

3. Gears made of polyimide in two different aircraft anti-collision lighting assemblies operate satisfactorily at very high ambient temperatures. These gears are strong enough for the high loads encountered, while operating continuously at 300°F. and higher.

4. Sterilizable medical equipment made from polyphenylene oxide is autoclavable and low in cost.

5. Enlarger printer for amateur photographers is molded from asbestos - reinforced polypropylene, a stiffer, more heat resistant material without sacrificing polypropylene's surface hardness, resistance to flexural fatigue, impact strength and resistance to chemicals and stress cracking.

6. Refrigerator door liners are thermoformed from a single sheet of high-impact styrene. They withstand slam-bang impacts of day-in and day-out service at refrigerator temperatures.

7. Animated toys benefit from the unusual toughness of extra high impact polystyrene.

8. Subminiature printed circuit card-edge connector at left, and rack-and-panel connector at right are precision molded from polysulfone.

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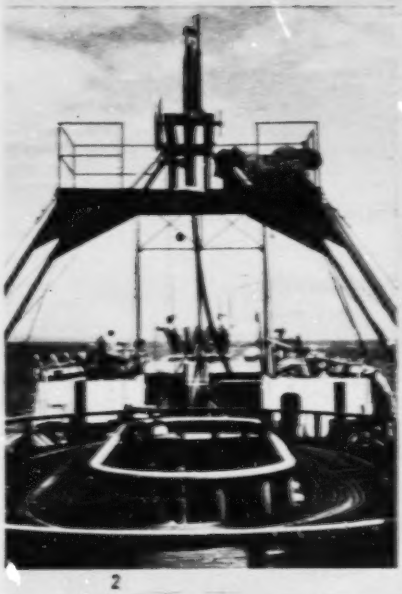

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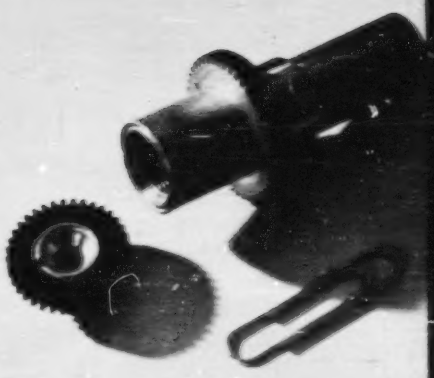

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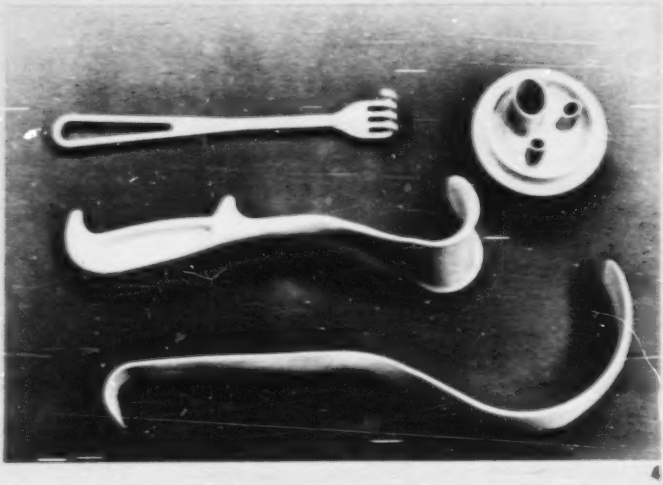

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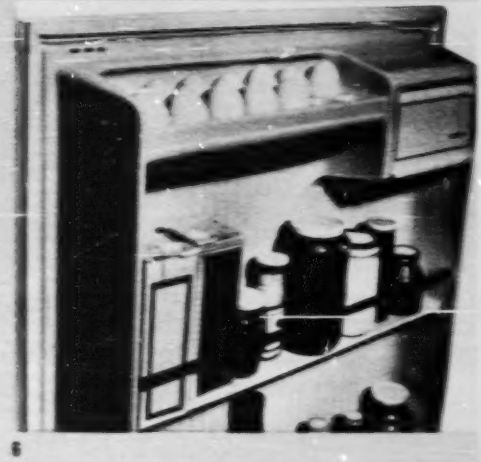

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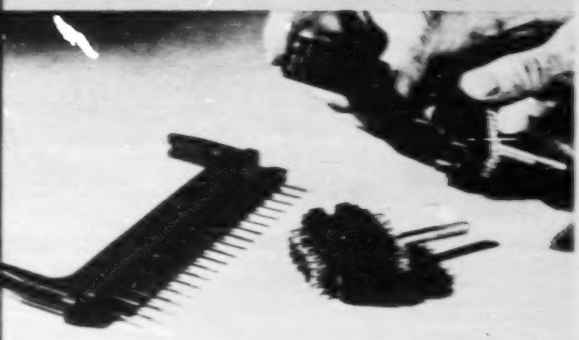

dielectric properties maintained over a wide temperature and frequency range.

Hydrolytic stability • Polyphenylene oxide resists steam, aqueous chemicals, acids and bases.

FORMS AND METHODS OF FABRICATION

Polyphenylene oxide resins are fabricated by all conventional techniques including extrusion and molding.

POLYPROPYLENE

Polypropylenes are thermoplastic materials first introduced in the United States in 1957. Production of polypropylene in 1967 reached 620,000,000 lbs.

TYPICAL USES

Safety helmets, pipes and fittings, valves, packaging film and sheets, sterilizable bottles, wire and cable insulation, battery boxes, refrigerator parts, waste baskets, tubs for washing machines, flexible hinges, housewares and household appliance parts.

PROPERTIES

Flex life • Polypropylenes have excellent flex life.

Mechanical • In general, polypropylene is an outstanding electrical insulation material. It has very low dielectric constant, essentially unaffected by frequency or temperature over ranges tested. It shows a low loss factor.

Surface hardness • The surface hardness and scratch and abrasion resistance of polypropylene are superior to other low-cost polymers.

FORMS AND METHODS OF FORMING

Polypropylene can be processed by injection molding, blow molding and extruded on conventional thermoplastic equipment. Films made of polypropylene may be heat-sealed with the same equipment used for polyethylene and can be laminated to paper, cloth or aluminum. Polypropylene is also produced as a foam plastic.

POLYSTYRENE OR STYRENE

Polystyrene is a thermoplastic. Developed in 1938, its production totaled an estimated 2,550,000,000 lbs. in 1967.

TYPICAL USES

Kitchen items, refrigerator food containers, toys, battery cases, instrument panels, wall tile, portable radio housings, premiums, are typical products made from polystyrene or styrene.

Styrene copolymers and terpolymers are available which offer greater toughness and impact properties, higher heat resistance, or other special qualities.

PROPERTIES

Optical qualities, color, texture • Polystyrene or styrene is available as a clear transparent, translucent or opaque material in a rainbow of colors. It can be produced with a smooth satiny surface or a special texture.

Tasteless, odorless.

Electrical qualities • Polystyrene or styrene has very good all-round dielectric properties.

Water and weather resistance • Articles made of polystyrene or styrene hold their dimensions well under conditions of normal use. It should not be exposed to continued outdoor use. The material's water absorption rate is low.

Resistance to heat and cold • Polystyrene or styrene is not harmed by continuous use at food freezer temperatures. It can be subjected, for short periods, to heat approaching the boiling point of water. If greater heat resistance is desired, a special type may be used. This plastic will burn slowly if subjected to a direct flame.

Chemical resistant • Most foods, drinks and usual household acids, oils, alcohol, vinegar, have no effect on polystyrene or styrene. This is not true, however, of citrus fruit rind oil, cleaning fluids, gasoline, turpentine, nail polish and remover, which will harm the material.

Strength • Polystyrene or styrene is hard and rigid and withstands ordinary household use. It is not recommended for articles subject to severe impact or flexing. Abrasives should be avoided when cleaning. For higher strength and impact resistance, glass-filled types are available.

FORMS AND METHODS OF FORMING

Polystyrene or styrene is available as molding powder and granules, sheets, rods and other shapes, foamed blocks, as liquid solutions and adhesives, coatings.

Finished products may be made from polystyrene or styrene by injection, compression molding and by extrusion, laminating and machining.

POLYSULFONE

Polysulfones are thermoplastic materials developed in 1965.

TYPICAL USES

Polysulfone finds wide use in appliance housings; "under-the-hood" automotive components; hand power tool housings; computer parts; switches; circuit breakers; extruded pipe, sheeting, and wire coatings; and in structural bonding and laminating formulations.

PROPERTIES

Resistant to extremes of temperature • Polysulfone possesses the highest use temperature of any melt processable thermoplastic and very low creep under load. It is inherently self-extinguishing. It maintains a high degree of its mechanical and electrical properties in continuous service at temperatures ranging from −150°F. to over 300°F.

Color • Supplied in a variety of transparent and opaque colors, polysulfone can be dry-colored with certain dyes.

Mechanical strength • Polysulfone has high tensile strength and modulus and a good stress-strain behavior pattern typical of rigid ductile materials.

Chemical and solvent resistance • Polysulfone is highly resistant to mineral acid, alkali, and

salt solutions. Resistance to detergents, oils and alcohols is good even at elevated temperatures under moderate levels of stress.

Electrical properties • Electrical properties of polysulfone are excellent over a wide temperature range and even after immersion in water or exposure to high humidity.

FORMS AND METHODS OF FORMING

Polysulfone resins may be used as adhesives and can be fabricated by extrusion, injection molding, blow molding and thermoforming. Formed parts can be processed by all standard machining methods, joined by solvent or heat sealing techniques, and surface decorated with ease.

POLYURETHANE OR URETHANE

Industrial interest in urethane plastics in this country has grown rapidly in recent years. Urethanes were introduced commercially in 1954.

TYPICAL USES

These versatile materials have been used for some time abroad for a variety of purposes and in many different forms, such as flexible to rigid foams, solid elastomers and plastics, coatings for wood, metal, wire and textiles, adhesives, bristles.

Urethane foams are favored for cushioning, mattresses, insulated clothing, padding, toys, packing, rug underlays, sponges, mats, crash pads, lightweight structural parts and appliance insulation.

Solid articles formed by molding, extrusion or casting include elastic printing rolls, abrasive wheels, cable insulation, automotive parts, bristles, tire treads, and airplane structures.

Urethane coatings impart outstanding protective and decorative effects to wood, metals, rubber, textiles, concrete, paper, leather, plastics and many other products.

PROPERTIES

SOLID MATERIALS:

Tough and shock resistant • Elastomeric types have unusual abrasion and tear resistance.

Adhesion • Isocyanates are among the few substances effective for adhering synthetic rubber to synthetic fibers in the manufacture of tires, and for uniting rubber with metals and ceramics. Urethanes are used as adhesives for bonding leather to leather, foams to various substrates, etc.

Resistance to chemicals and other agents • The cured plastics are remarkably resistant to a wide variety of deteriorating agents, such as common chemicals, including organic solvents, and petroleum products. Water-, moisture-, rot- and vermin-proof. Special polymers can be compounded to be flame-resistant.

FOAMED MATERIALS:

Flexible foams can be made in a broad range of firmness and resilience and in varying densities. These foams have properties suitable for cushioning, shock- and sound-absorption, and heat insulation. Rigid foams are beginning to find large use as thermal insulation. Because urethanes can be foamed-in-place, their areas of use are greatly enhanced.

FORMS AND METHODS OF FORMING

SOLID TYPE:

Fabrication is generally carried out starting with two reactants, polyisocyanate and polyol. These raw materials are supplied as liquid or solid organic di-isocyanates, to be combined with special polyesters or polyethers or as prepolymers (partially reacted). Final articles can be extruded, molded, calendered, or cast in shapes as desired. They are then cured to final form.

FOAMED TYPE:

The raw materials are polyols, polyisocyanates, water and catalyst mixtures. Foams can be made by either a prepolymer or one-shot process, in both slab stock and also in molded forms.

SILICONE

Silicones were commercialized in the early 1940's.

TYPICAL USES

The big outlets for silicones are in the electrical industry where they are used for coil forms, switch parts, induction heating apparatus, as insulation for motors and generator coils, and in power cables.

In thermoplastic and thermosetting resin systems silicone coupling agents are used to strengthen the bond between glass fibers or mineral fillers and resins. As little as 0.001% silicone (based on total weight) can double the strength of glass/reinforced thermoplastics.

PROPERTIES

Heat resistant • Silicones exhibit high heat stability. Silicone insulation has shown itself highly stable up to 350°F to 590°F, depending on whether it is used with glass fiber, mica, or asbestos.

Electrical qualities • Silicones have very good dielectric properties, particularly after exposure to moisture and elevated temperatures. They offer a low power factor over a wide frequency range.

Chemical and water resistant • Silicones are water repellent, weather resistant and highly resistant to mineral acids, and also corrosive salt solutions.

FORMS AND METHODS OF FORMING

Silicones are available as molding compounds, resins, coatings, greases, fluids and as silicone rubber.

They may be made into finished articles by: compression and transfer molding, extrusion, coating, calendering, impregnating, laminating, foaming, casting.

VINYL

The vinyls, which are thermoplastic materials, are produced in seven major types. Introduced in 1927, all the vinyls were estimated as totaling 2.8 billion lbs. in 1967.

TYPICAL USES

The vinyls are produced in several forms: flexible or elastomeric, inflexible or rigid, cellular or foam.

They are familiar as raincoats, garment bags, inflatable water toys, shower curtains, upholstery, draperies, garden hose, wire and cable insulation, phonograph records, clear blow-molded packaging containers, gaskets, weatherstrip, electric plugs, floor and wall covering and coated materials.

PROPERTIES

Strong and abrasion resistant • All types of vinyls are tough and strong, though only the flexible types can be bent back and forth without weakening or tearing. The surface of all vinyls resists the abrasion of normal use and special types are available with very high wear resistance. Abrasive cleaners should not be used.

Chemical and water resistant • Vinyls, with the exception of some non-rigid types, are unaffected by prolonged contact with water, oils, foods, common chemicals and cleaning fluids such as gasoline and naphtha. They should all be kept away from chlorinated solvents, nail polish and remover, and moth repellents. Vinyls enjoy a very slow rate of water absorption.

Resistance to heat and cold • Vinyls in general withstand continuous exposure to temperatures up to 130°F., the range usually encountered in household operation. Flexible types and filaments are unaffected by higher temperatures. On the cold side, vinyls perform satisfactorily at food freezing temperatures. Vinyls are slow burning; certain types self-extinguishing. They should be kept from contact with direct heat.

Wide color range • Vinyls are produced in clear form and in a wide range of colors which

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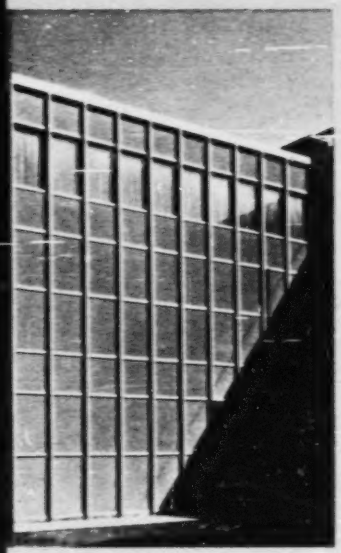

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1. Trim straight lines of modern furniture are assured by use of long-lasting polyurethane foam cushions, which will retain their shape despite long wear, while offering exceptional seating comfort.

2. Flexible "concrete"—a new construction material that looks like concrete, but can be bent like rubber. The base compound is a space-developed silicone rubber. The material is used as a topping for highways, patios, swimming pools. It withstands the ravages of weather, water, freezing and cracking.

3. Lightweight, weather resistant polyvinyl chloride is used in modern homes for gutters, down spouts, leaders and siding.

4. Vinyl-chloride acetate sheeting finds use as liners for ponds, reservoirs and irrigation ditches, effectively preventing loss of water due to seepage.

5. Exterior vinyl-metal laminates decorate this laboratory building. Application involves vinyl laminated to aluminum with a sandwich of polyurethane foam and gypsum board. This board is, in turn, laminated with interior vinyl which becomes the interior wall.

6. Young traveler rides in luxurious comfort on a padded car seat made from soft vinyl foam.

may be clear, translucent or opaque. They may be printed or embossed.

Weathering • Vinyls are generally recommended for indoor use, though special types are made for use out-of-doors.

Electrical qualities • Vinyls generally have excellent electrical properties.

TYPES

Polyvinyl acetal • This type vinyl falls into three groups: polyvinyl formal, polyvinyl acetal and polyvinyl butyral. Polyvinyl butyral is familiar as the interlayer for safety glass.

Polyvinyl acetate • This vinyl material is odorless and tasteless, slow-burning, colorless, insoluble in water, fats, waxes and aliphatic hydrocarbons. It is used for heat-sealing films, flashbulb linings, paints, adhesives.

Polyvinyl alcohol • This vinyl is characterized by its imperviousness to all water insoluble solvents and gases, animal and vegetable oils. It is strong and abrasion resistant. It is used in paper coating and sizing. Cast polyvinyl alcohol is used as a mold release in molding polyester resins with glass fiber for airplane parts, boats, etc. Internally plasticized polyvinyl alcohol is used as a water soluble film for packaging soaps, detergents, dyes.

Polyvinyl carbazole • This vinyl is characterized by its combination of desirable electrical properties. Typical applications are structural components for low-loss electrical assemblies.

Polyvinyl chloride • This vinyl can be made in a wide range of flexibility. It offers unlimited colors, toughness and high resistance to acids, alkalies and alcohol. It has wide use as pipe and extruded profiles, wire and cable insulation, work gloves, flooring, upholstery and foam applications. It is also produced as film and sheeting.

Polyvinyl chloride-acetate • Available in rigid and flexible form. It is familiar in shower curtains, rainwear, phonograph records, shoe soling, wire insulation, coated fabrics, surface coatings.

Polyvinylidene chloride • This vinyl may be made into both flexible and rigid form. It is familiar as an extruded monofilament which is woven into upholstery fabric and screening. It is also used as pipe and tubing.

FORMS AND METHODS OF FORMING

Polyvinyl acetal is available as molding powder, sheet, rod and tube. It can be formed by: molding, extruding, casting, calendering.

Polyvinyl acetate is available as granules, film-forming emulsions, adhesives.

Polyvinyl alcohol is available as molding powder, sheets, film, tube and rod. It can be formed by: molding, extrusion, casting.

Polyvinyl carbazole is available as powder, lumps, film. It can be made into articles by: compression and injection molding, casting.

Polyvinyl chloride is available as resins, latices, coatings, organosols, plastisols, compounds. It can be made into finished products by molding, extrusion, calendering.

Polyvinyl chloride-acetate is available as molding powders, organosols, plastisols, sheets, rods, tubes. It can be made into finished products by compression, injection and slush molding, calendering, casting, extrusion and as coatings.

Polyvinylidene chloride is available as molding powder, sheets, rods, tubes. It can be made into products by injection, compression, transfer molding, extrusion, casting.

Processing Plastics

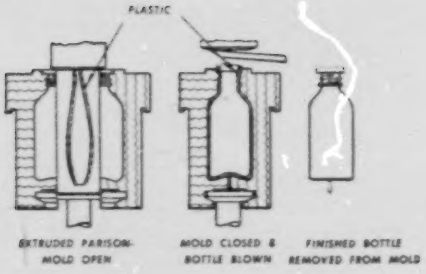
BLOW MOLDING

Blow molding is a method of forming used with thermoplastic materials.

Basically, blow molding consists of stretching and then hardening a plastic against a mold. There are two general methods of doing this type of thermoplastic molding: the direct method and the indirect method, encompassing several variations of each.

In the direct method, a gob of molten thermoplastic material is formed into the rough shape of the desired finished product. This shape is then inserted in a female mold and air blown into the plastic, as into a balloon, to force it against the sides of the mold. The formed material is then cooled before removal from the mold.

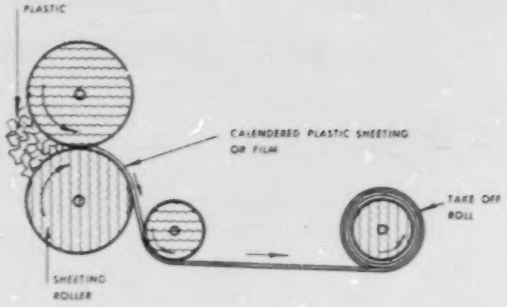
In the indirect method, a thermoplastic sheet or special shape is first heated, then clamped between a die and cover. Air pressure forced between the plastic and the cover forces the material into contact with the die, which has the contour desired in the finished product. The plastic is cooled before removal from contact with the die.



BLOW MOLDING

CALENDERING

Calendering can be used to process thermoplastics into film and sheeting, and to apply a plastic coating to textiles or other supporting materials. Film refers to thicknesses up to and



CALENDERING

including 10 mils, while sheeting includes thicknesses over 10 mils.

In calendering film and sheeting, the plastic compound is passed between a series of three or four large, heated, revolving rollers which squeeze the material between them into a sheet or film. The thickness of the finished material is controlled by the space between the rolls. The surface of the plastic film or sheeting may be smooth or matted, depending on the surfacing on the rollers.

In applying a plastic coating to a fabric or other material by the calendering process, the coating compound is passed through two top horizontal rollers on a calender, while the uncoated material is passed through two bottom rollers, emerging as a smooth film which is anchored to the fabric when fabric and film pass between the same rolls.

CASTING

Casting may be employed for both thermoplastic and thermosetting materials in making special shapes, rigid sheets, film and sheeting, rods and tubes.

The essential difference between casting and molding is that no pressure is used in casting as it is in molding.

In casting, the plastic material is heated to a fluid mass, poured into either open or closed molds, cured at varying temperatures depending on the plastic used, and removed from the molds.

Casting of film (and some sheeting) is done on a wheel or belt, or by precipitation in a chemical bath.

In the case of wheel or belt casting, the plastic is spread to the desired thickness on the wheel or belt as it revolves or moves and as the temperature is increased. The film is then dried and stripped off.

COATING

Thermosetting and thermoplastic materials may both be used as a coating. The materials to be coated may be metal, wood, paper, fabric, leather, glass, concrete, ceramics or other plastics.

Methods of coating are varied and include knife or spread coating, spraying, roller coating, dipping, and brushing. Calendering of a film to a supporting material, described under calendering, is also a form of coating. A new method for applying plastics to metals is called the fluidized bed process.

In spread coating, the material to be coated passes over a roller and under a long blade or knife. The plastic coating compound is placed on the material just in front of the knife, and is spread out over the material. The thickness of the coating is regulated by the speed at which the material is drawn under the knife, and the position of the knife.

In roller coating, two horizontal rollers are used. One roller picks up the plastic coating solution on its surface and deposits it on the second roller which, in turn, deposits the coating solution on the supporting material.

A plastic coating may also be applied by spraying it through a spray gun or by brushing it over the material to be coated as in silk screen work. Articles to be coated may also be dipped into a solution of plastics until the desired thickness of coating is achieved, and then dried.

COMPRESSION MOLDING

Compression molding is the most common method of forming thermosetting materials. It is not generally used for thermoplastics.

Compression molding is simply the squeezing of a material into a desired shape by application of heat and pressure to the material in a mold.

Plastic molding powder, mixed with such materials or fillers as woodflour, cellulose and asbestos to strengthen or give other added qualities to the finished product, is put directly into the open mold cavity. The mold is then closed, pressing down on the plastic and causing it to flow throughout the mold. It is while the heated mold is closed that the thermosetting material undergoes a chemical change which permanently hardens it into the shape of the mold. The three compression molding factors – pressure, temperature and time the mold is closed – vary with the design of the finished article and the material being molded.

EXTRUSION

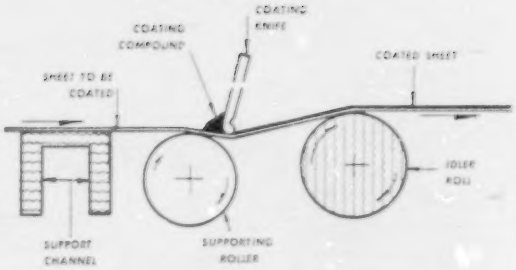
Extrusion molding is the method employed to form thermoplastic materials into continuous sheeting, film, tubes, rods, profile shapes, filaments, and to coat wire, cable and cord.

In extrusion, dry plastic material is first loaded into a hopper, then fed into a long heating chamber through which it is moved by the action of a continuously revolving screw. At the end of the heating chamber the molten plastic is forced out through a small opening or die with the shape desired in the finished product. As the plastic extrusion comes from the die, it is fed onto a conveyor belt where it is cooled, most frequently by blowers or by immersion in water.

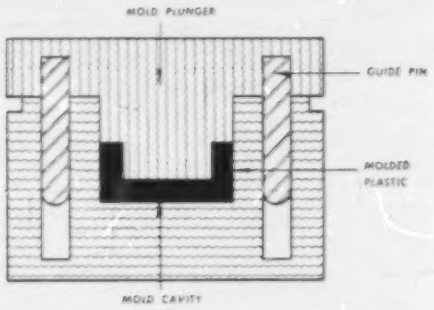
In the case of wire and cable coating, the thermoplastic is extruded around a continuing length of wire or cable which, like the plastic, passes through the extruder die. The coated wire is wound on drums after cooling.

In producing wide film or sheeting, the plastic is extruded in the form of a tube. This tube may be split as it comes from the die and then stretched and thinned to the dimensions desired in the finished film.

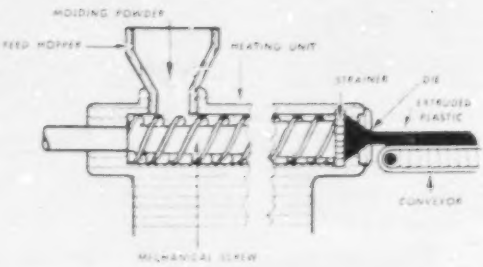
In a different process, the extruded tubing is inflated as it comes from the die, the degree of inflation of the tubing regulating the thickness of the final film.



COATING



COMPRESSION MOLDING



EXTRUSION MOLDING

FABRICATING

Fabricating covers operations on sheet, rod, tube, sheeting, film and special shapes to make them into finished products. The materials may be thermosetting or thermoplastic.

Fabricating divides into three broad categories – machining; cutting, sewing and sealing of film and sheeting; and forming.

Machining:

Machining is used on rigid sheets, rods, tubes and special shapes. The various operations include grinding, turning on a lathe, sawing, reaming, milling, routing, drilling, tapping.

Cutting, sewing, sealing of film and sheeting:

In this category of fabricating fall all the operations involved in fashioning plastic film and sheeting into finished articles like inflatable toys, garment bags, aprons, raincoats, luggage.

For all these articles, the film or sheeting must first be cut to pattern. This cutting may be done in a press by a power-driven hand-operated knife or by other methods.

It remains to join the various pieces of film. This may be done by sewing or heat sealing. Cements are rarely used in fabricating film.

Forming:

In working with flexible thermoplastic sheets, the first step is usually the cutting or blanking out of sections roughly approximating the dimensions of the finished article. This blank may be beaded for added strength, creased and folded into final form – a box, for example. Or deep drawing may be employed, using male and female molds to shape the plastic blank.

Rigid sheet may also be molded to final form. There are a number of methods of thus shaping a sheet. In vacuum forming or molding, the heated sheet is clamped to the top of a female mold and either drawn down into the mold by vacuum or forced down by air pressure. In snapback forming, the heated sheet is drawn into a vacuum pot and a male mold lowered inside the bubble formed by the sheet. As the vacuum is released the hot sheet snaps back against the male mold.

In addition, rigid sheets can be fabricated into finished products by welding them together as in thermoplastic structural products. These items include hoods, venting systems, duct work, tank liners, storage tanks, machinery covers, and other allied products.

The welding torch itself is perhaps the most important piece of equipment used in this process. There are two basic types of torches available which accomplish this procedure satisfactorily. The first and more popular is the torch which heats the welding gases electrically. The second type uses an open flame of either acetylene or propane gas which transfers its heat to a coil through which the welding gas is passed.

Standard procedures as established by the industry should be utilized to evaluate welding performance of thermoplastic structures.

FINISHING

The finishing of plastics includes the different methods of adding either decorative or functional surface effects to a plastic product.

Film, sheeting and coated materials:

These forms of plastics may have the texture of their surface changed, either during processing or after, by being pressed against a heated roller or mold that is embossed with a pattern.

Colorful patterns may also be printed on the surface of film, sheeting and coated material either by letter press, gravure or silk screening.

Rigid plastics:

There are a wide variety of methods of adding decorative effects to the surface of rigid plastic parts. One is metal plating, accomplished through metal spraying, vacuum deposition or metal dusting and painting.

Other means of decorating involve stamping the finished product, printing by silk-screen or offset, engraving, etching or air blasting.

Molded Products:

Decorative textures on molded products are often achieved by incorporating them into the molds.

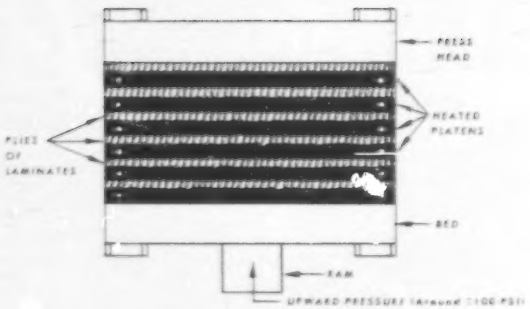
HIGH-PRESSURE LAMINATING

Thermosetting plastics are most generally used in high-pressure laminating which is distinguished by the use of high heat and pressure. These plastics are used to hold together the reinforcing materials that comprise the body of the finished product. The reinforcing materials may be cloth, paper, wood, fibers of glass.

The end product of high-pressure laminating may be plain flat sheets, decorative sheets as in counter tops; rods, tubes or formed shapes.

Whatever the final shape, the first step in high-pressure laminating is the impregnating of the reinforcing materials with plastics.

In producing a flat surface, impregnated sheets are stacked between two highly polished steel plates and subjected to heat and high pressure in an hydraulic press which cures the plastic and presses the plies of material into a single piece of the desired thickness. In making high-pressure tubing, resin-treated reinforcing sheets are wrapped, under tension and/or pressure, around a heated rod. The assembly is then cured in an oven. In producing formed shapes, the reinforcing material is cut into pieces that conform to the contour of the product, fitted into the mold and cured under heat and pressure.

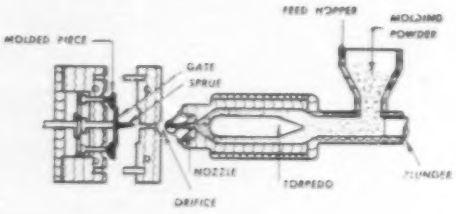


HIGH-PRESSURE LAMINATING

INJECTION MOLDING

Injection is the principal method of forming thermoplastic materials. Modifications of the injection process are sometimes used for thermosetting plastics.

In injection molding, plastic material is put into a hopper which feeds into a heating chamber. A plunger pushes the plastic through this long heating chamber where the material is softened to a fluid state. At the end of this chamber there is a nozzle which abuts firmly against an opening into a cool, closed mold. The fluid plastic is forced at high pressure through this nozzle into the cold mold. As soon



INJECTION MOLDING

as the plastic cools to a solid state, the mold opens and the finished plastic piece is ejected from the press.

The problem with injection molding of thermosetting materials is that, under heat, these plastics will first soften, then harden to an infusible state. Thus it is essential that no softened thermosetting material in the heating chamber be allowed to remain there long enough to set.

Jet molding, offset molding and molding using a screw-type machine overcome this problem by liquefying the thermosetting plastic material just as it goes through the injection nozzle into the mold, but not before.

PULP MOLDING

Thermosetting plastics are used in pulp molding.

In this process a porous form, approximating the shape of a finished article, is lowered into a tank containing a mixture of pulp, plastic resins and water. The water is drawn off through the porous form by a vacuum. This causes the pulp and resin mixture to be drawn to the form and adhere to it. When a sufficient thickness of pulp has been drawn onto the form, it is removed and then molded into final shape.

REINFORCING

Reinforced plastics mostly employ thermoset plastics, though some thermoplastics are used.

Reinforced plastics differ from high-pressure laminates in that very low or no pressure is used in the processing. The two methods are alike in that in both, the plastic is used to bind together the cloth, paper or glass fibers reinforcing material used for the body of the product. The reinforcing materials may be in sheet or mat form, and their selection depends on the qualities desired in the end product.

Reinforced plastics offer exceptionally high strength with low weight. Also, they lend themselves to easy, economical fabrication, requiring relatively little pressure and heat for curing, and employing types of molds and other equipment that represent a fraction of the investment cost for metal fabricating dies and machinery. Thus, they make possible considerably larger plastics products.

A number of different techniques may be employed in the production of reinforced plastics. In making formed shapes, impregnated reinforcing material is cut in accordance with the shape of the finished product into one piece or a number of pieces. The pattern or patterns are placed on a male mold in enough volume to give the final thickness and form. Molding is completed in heated, mated dies. A single mold may be used. The impregnated reinforcing material may be laid up on a male mold, inserted in a rubber bag from which all air is withdrawn so the bag presses around the layup, and cured in an oven. If a female mold is used, a diaphragm is placed over the end of the mold so that when air is withdrawn from within the mold, the diaphragm is drawn down inside the mold to press against the layup of resin impregnated materials.

In producing a continuous laminate, a web of reinforcing material passes through a bath of plastic resin, between rolls or under wiper bars that remove excess resin, and then between sheets of cellophane or coated paper. Thus protected, top and bottom, the material goes through the curing oven. After curing, the cellophane or paper is stripped off.

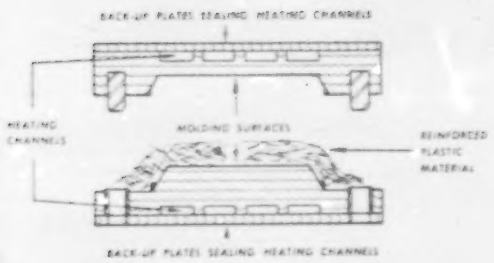
ROTATIONAL MOLDING

This technique is used to fabricate hollow, one-piece flexible parts from vinyl plastisols or from polyethylene powders.

Essentially, rotational molding consists of charging a measured amount of resin into a warm mold which is rotated in an oven about two axes. Centrifugal force distributes the plastic evenly throughout the mold and the heat

melts and fuses the charge to the shape of the cavity. After removing and cooling the mold, the finished part is extracted. Rotational molding is particularly suited to the production of very large parts, size being limited only by the capacity of the oven.

The advantages of this type of molding are: low mold cost, strain-free parts, and uniform wall thickness.



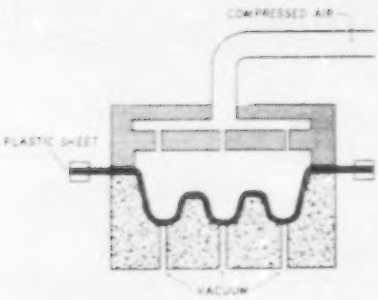
REINFORCING

SOLVENT MOLDING

Thermoplastic materials are used in this process of forming.

Solvent molding is based on the fact that when a mold is immersed in a solution and withdrawn, or when it is filled with a liquid plastic and then emptied, a layer of plastic film adheres to the sides of the mold.

Some articles thus formed, like a bathing cap or vial, are removed from the molds. Other solvent moldings remain permanently on the form as, for example, a plastic coating on a metal tube.



SHEET FORMING

THERMOFORMING

Thermoforming of plastic sheet has developed rapidly in recent years. Basically, this process consists of heating thermoplastic sheet to a formable plastic state and then applying air and/or mechanical assists to shape it to the contours of a mold.

Air pressure may range from almost zero to several hundred psi. Up to approximately 14 psi (atmospheric pressure), the pressure is obtained by evacuating the space between the sheet and the mold in order to utilize this atmospheric pressure. This range, known as *vacuum forming*, will give satisfactory reproduction of the mold configuration in the majority of forming applications.

When higher pressures are required, they are obtained by sealing a chamber to the top side of the sheet and building pressure within by compressed air. This system is known as *pressure forming*.

Essentially, vacuum and pressure forming are variations of the same basic technique, even though the difference in the formed parts may be significant.

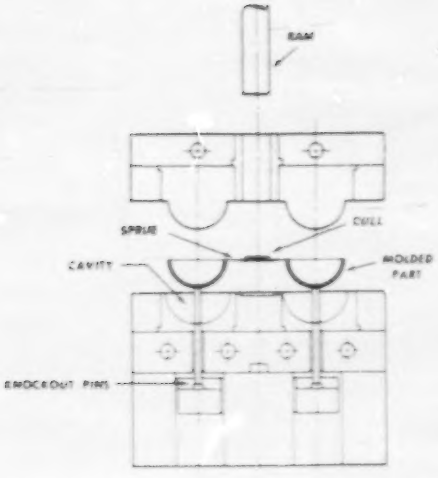
Variations of thermoforming include: straight forming; drape forming; plug and ring forming; slip forming; snap-back forming; reverse-draw forming; air slip forming; plug-assist forming; plug-assist-air-slip forming; and machine die forming.

TRANSFER MOLDING

Transfer molding is most generally used for thermosetting plastics.

This method is like compression molding in that the plastic is cured into an infusible state in a mold under heat and pressure. It differs from compression molding in that the plastic is heated to a point of plasticity before it reaches the mold and is forced into a closed mold by means of an hydraulically-operated plunger.

Transfer molding was developed to facilitate the molding of intricate products with small deep holes or numerous metal inserts. The dry molding compound used in compression molding sometimes disturbs the position of the metal inserts and the pins which form the holes. The liquefied plastic material in transfer molding flows around these metal parts without causing them to shift position.



TRANSFER MOLDING

Educational Facilities

Each year more schools, colleges and universities are adding instructions in plastics to their curricula. As interest grows, new courses are added, old courses realigned to better prepare students for the needs of the plastics industry.

Trade Publications and Books

A wealth of information is contained in trade and technical magazines and technical books for and about the plastics industry. A listing of these publications is available.

Films About Plastics

The Society of the Plastics Industry, Inc., has a list of motion picture films, film strips and slides that are available from various organizations for showing. The list describes the subject of each slide or film.

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